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(NASA-TM-X-67676) LUNAR SURFACE MAGNETOMETER DESIGN REVIEW (NASA) 23 Mar. 1970 132 p
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G3/14 21832

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

AMES
RESEARCH
CENTER

Moffett Field,
California

LUNAR SURFACE MAGNETOMETER
DESIGN REVIEW
MARCH 23, 1970

FOR

Manned Spacecraft Center

AT

National Aeronautics and Space Administration
Space Science Division
Moffett Field, California 94035

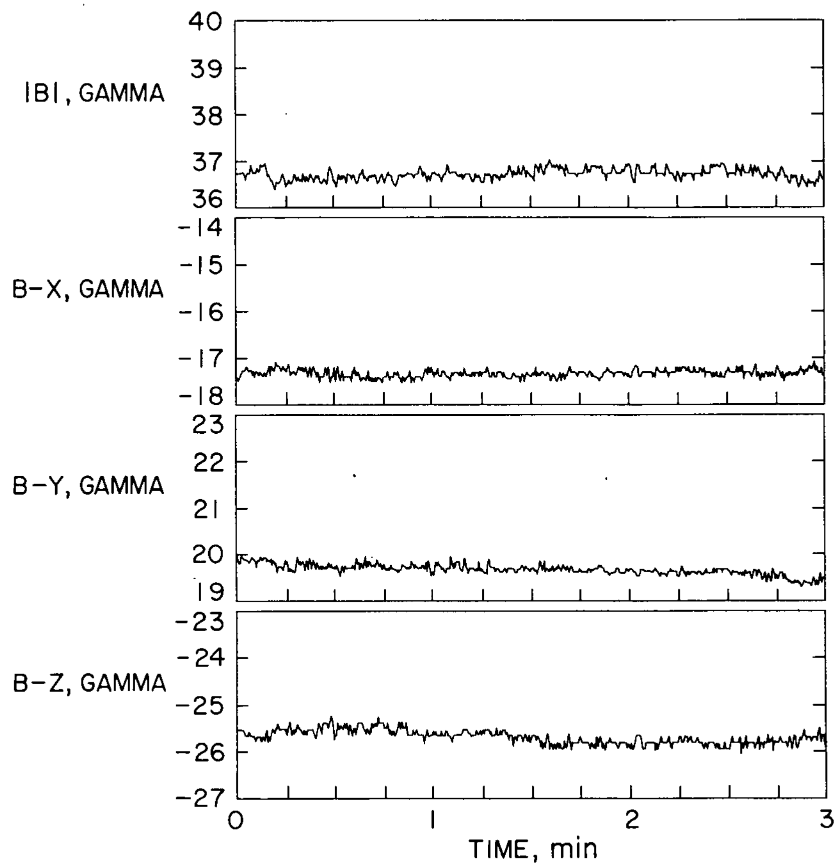
LSM DESIGN REVIEW AGENDA

A.	SCIENTIFIC OBJECTIVES AND OPERATIONAL EXPERIENCE	Dr. Sonett Dr. Dyal
B.	ELECTRONIC SUBSYSTEM DESIGN Design Requirements and Philosophy Block Diagram Interface Requirements Development Testing	H. Roberts
C.	MECHANICAL DESIGN Design Requirements Interface Requirements Human Factors Development Testing	W. Nelms
D.	ELECTRONIC PACKAGING DESIGN Packaging Constraints and Approaches Development Testing	B. Lieb
E.	THERMAL DESIGN Design Requirements Thermal Modeling & Results GSFC & Bendix Test Results Lunar Temperatures	C. Zierman and J. Arveson
F.	QUALITY ASSURANCE Reliability and Quality Assurance Requirements Organization and Planning Parts Selection Qualification and Screening Control of Procured Items In-process Inspections and Controls Test Control	T. Whittemore
G.	TESTING Electronics Subsystem IPT System Testing GSFC and Bendix Tests	 M. Felgen J. Fairman Dr. Dyal
H.	ANOMALIES REVIEW	
I.	DISCUSSION	

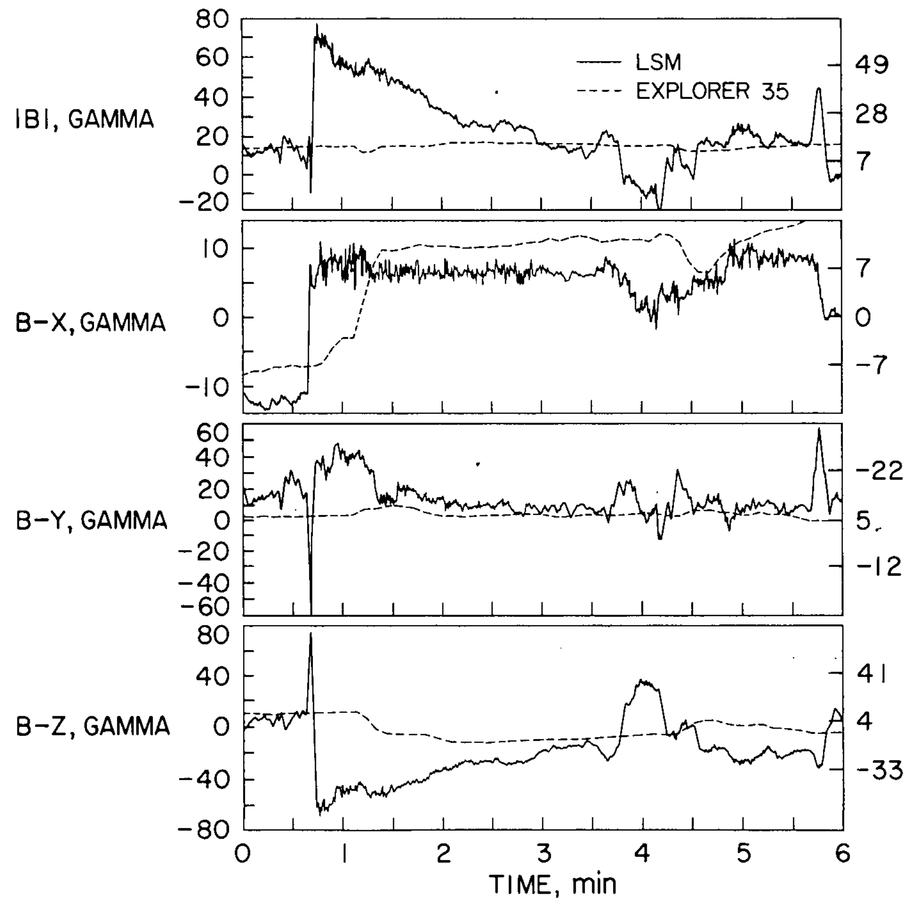
SCIENTIFIC OBJECTIVES AND OPERATIONAL EXPERIENCE

GEOMAGNETIC TAIL DATA

MAGNETIC FIELD - ALSEP I COORD

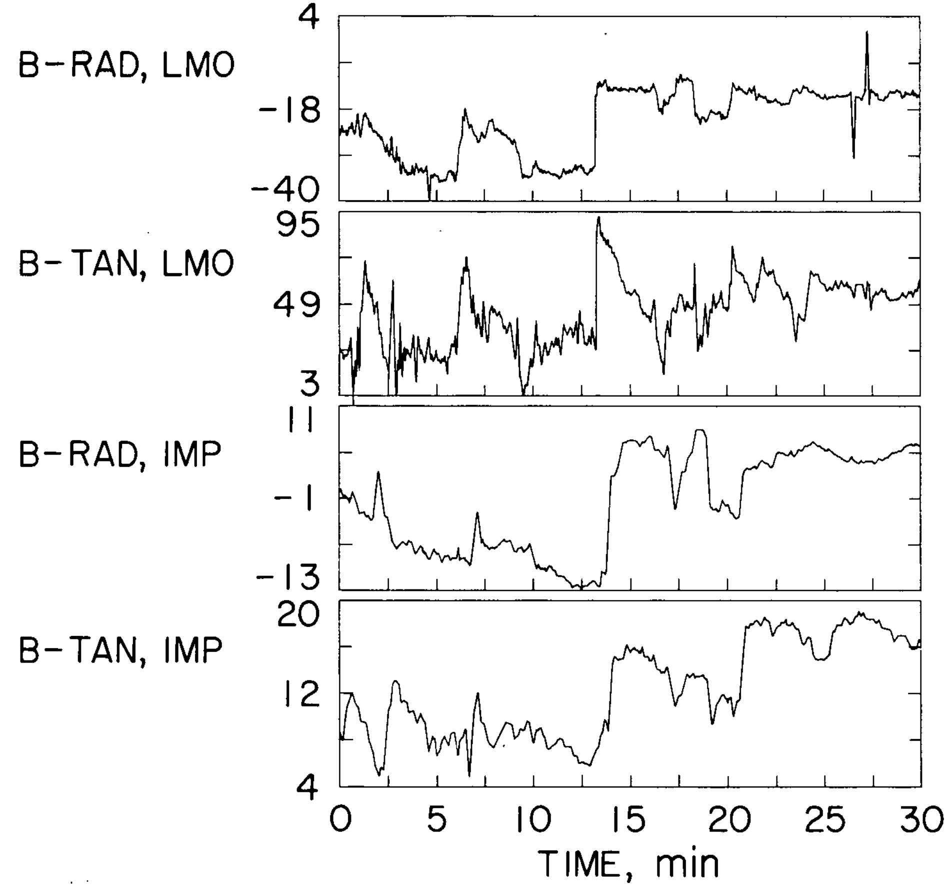


LUNAR RESPONSE TO MAGNETOSHEATH TANGENTIAL DISCONTINUITY



-SONETT

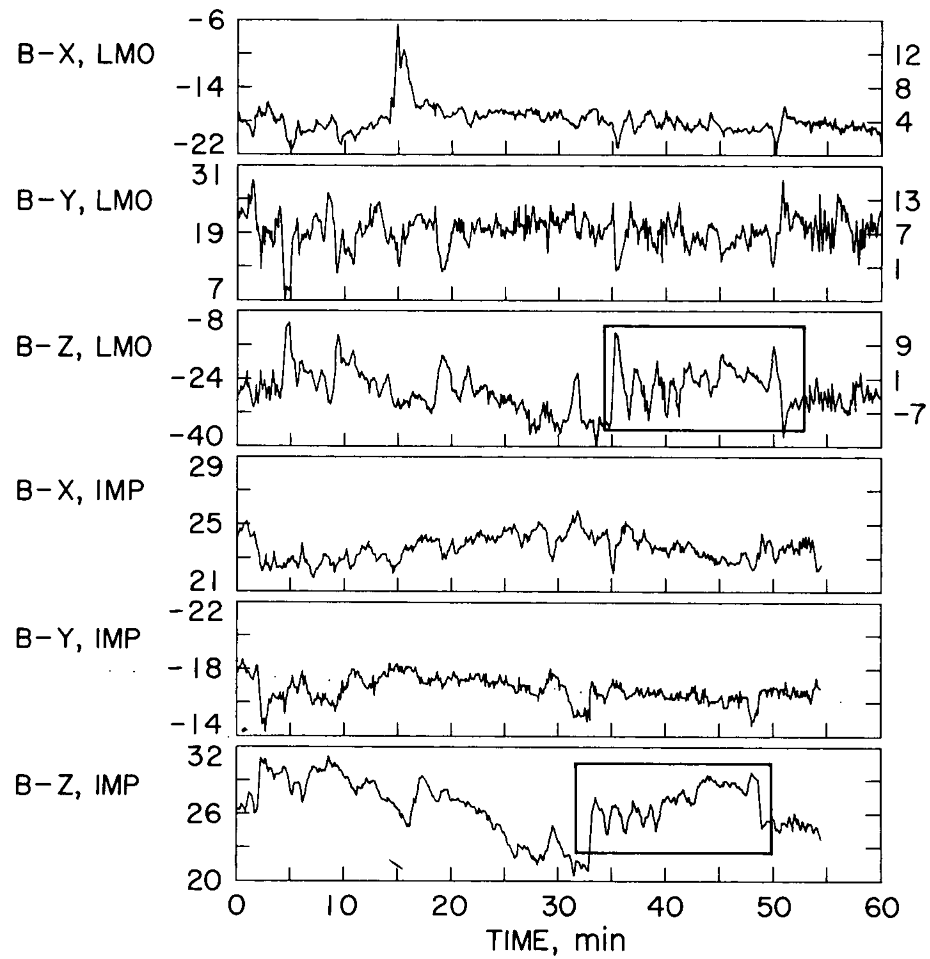
LMO, INTERPLANETARY FIELDS - ALSEP I COORD



9AB461-11

SONETT

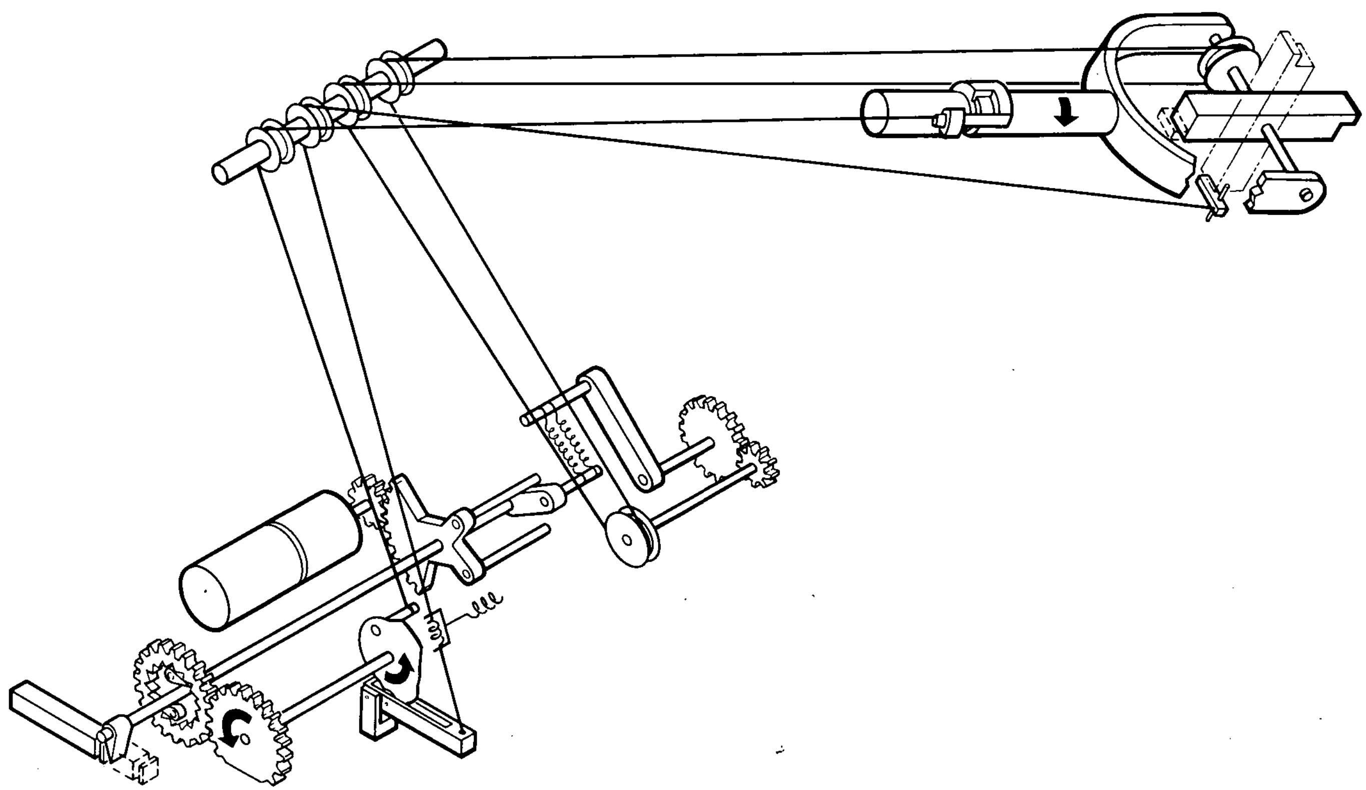
LMO. MAG. SHEATH FIELDS - ALSEP I COORD



AAB461-12

SONETT

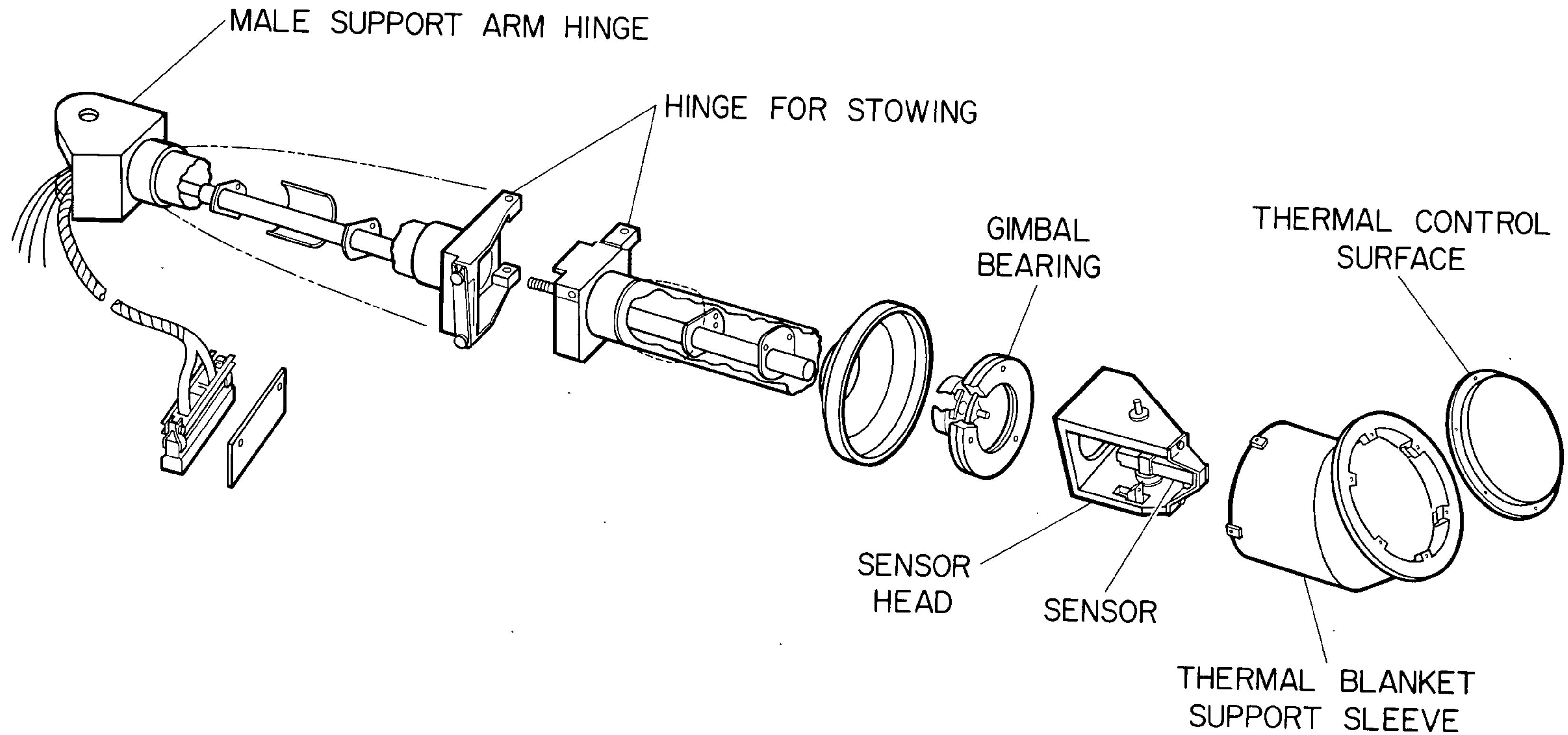
GIMBAL FLIP UNIT AND SENSOR HOUSING



AAB 461-13

SONETT

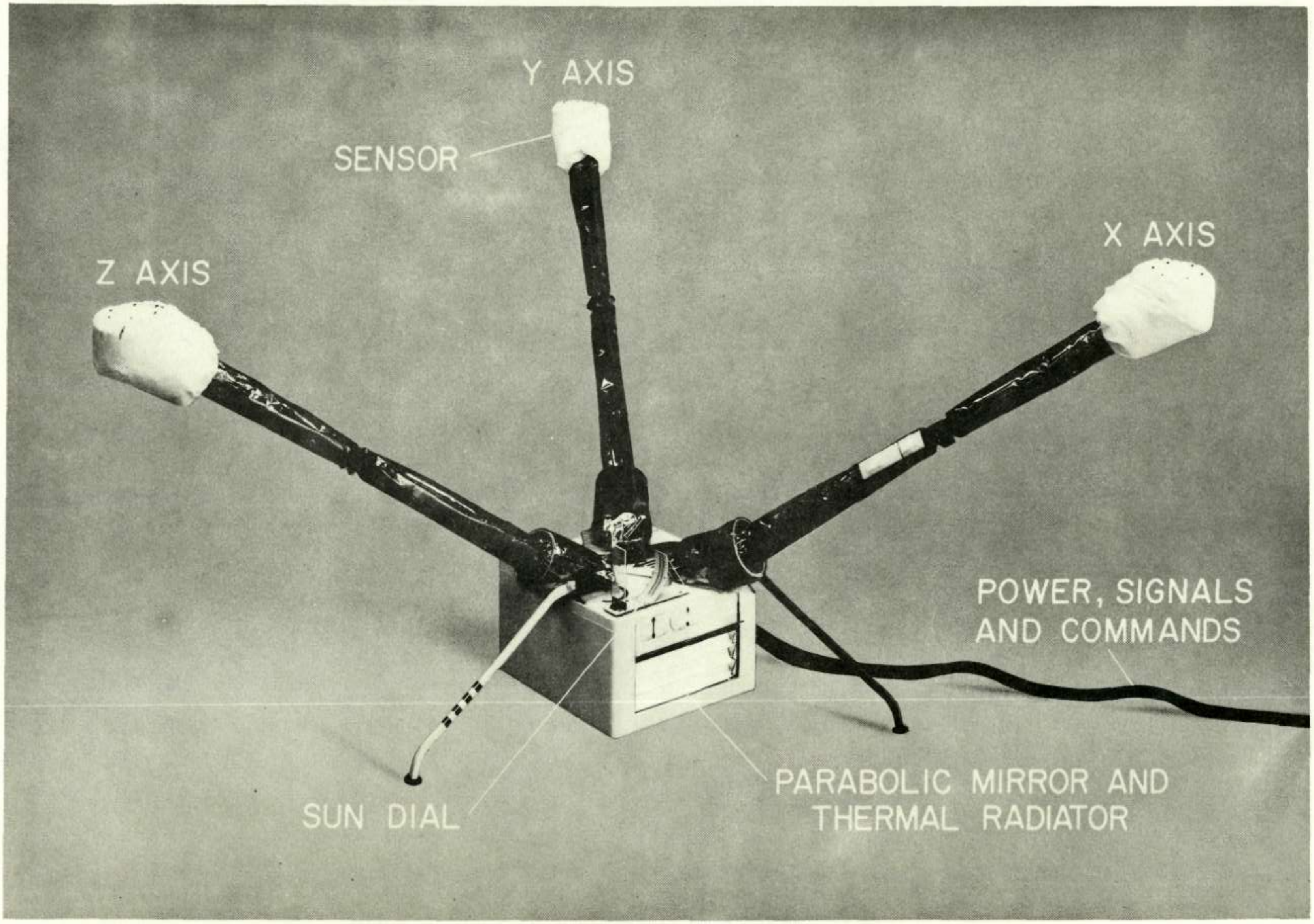
SENSOR ARM ASSEMBLY "Z" AXIS



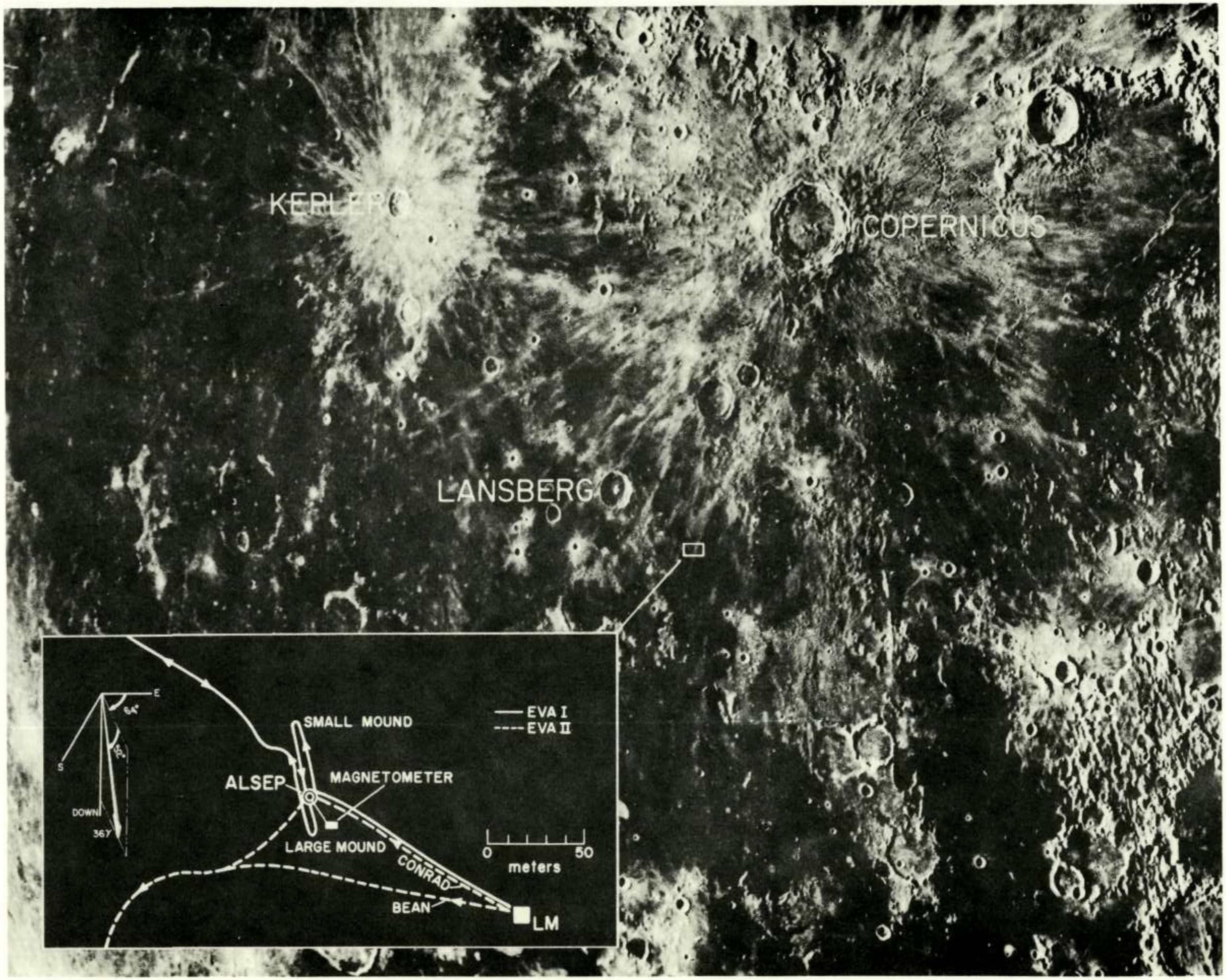
AAB 461-14

SONETT

LUNAR SURFACE MAGNETOMETER

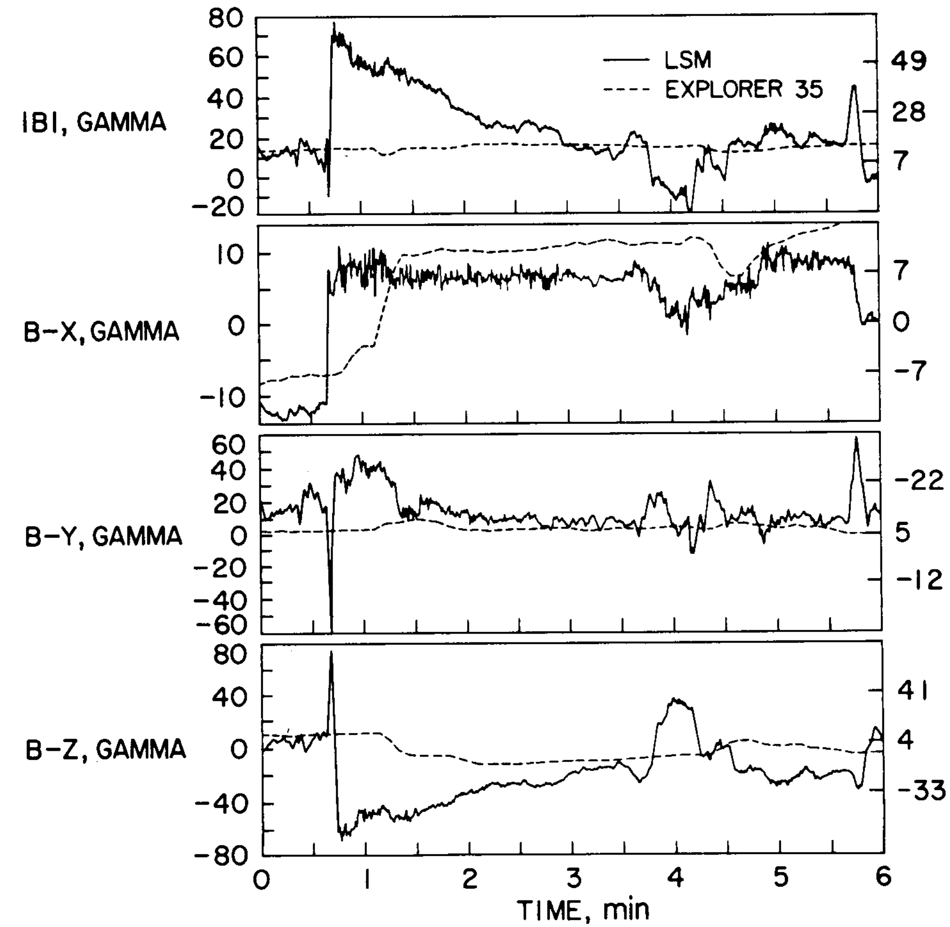


APOLLO 12 LANDING SITE



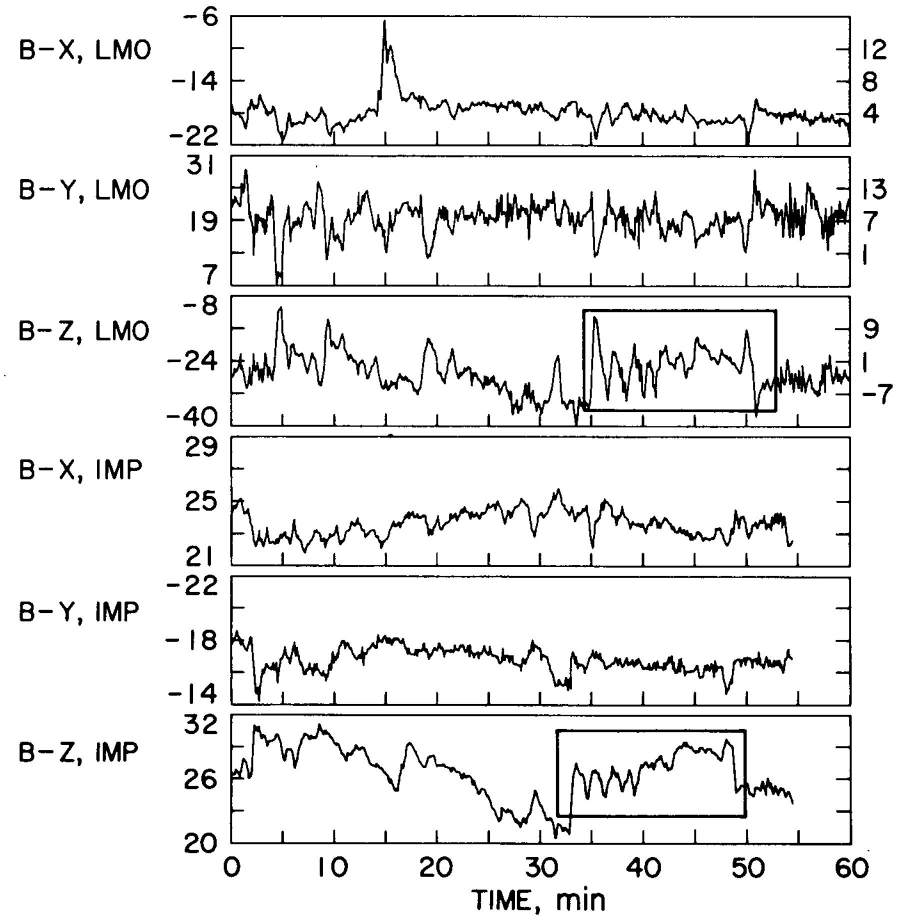
DISCONTINUITY NEAR MAGNETOPAUSE

LUNAR RESPONSE TO MAGNETOSHEATH TANGENTIAL DISCONTINUITY



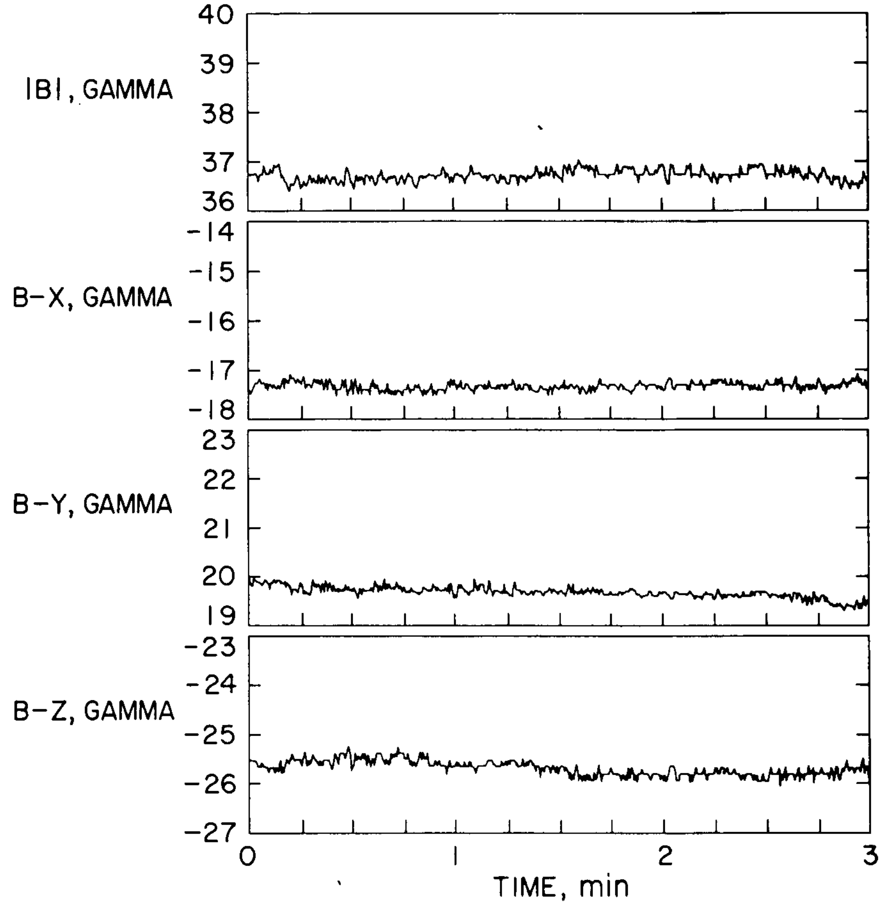
APOLLO 12 AND EXPLORER 35 CORRELATION DATA

LMO. MAG. SHEATH FIELDS - ALSEP I COORD



GEOMAGNETIC TAIL DATA

MAGNETIC FIELD - ALSEP I COORD



G. TEST HISTORY CONTINUED

ALSEP SYSTEMS TESTS AT BENDIX

1. BRASSBOARD ELECTRICAL INTERFACE TEST
2. HUMAN FACTORS, ASTRONAUT TRAINING MODEL
3. MECHANICAL MODEL TESTS
4. ELECTRICAL BREADBOARD TESTS
5. ENGINEERING MODEL TESTS
6. PROTOTYPE TESTS
7. QUALIFICATION MODEL TESTS
8. FLIGHT 1 TESTS
9. FLIGHT 2 TESTS
10. TEST LIST

    A. PRELIMINARY INTEGRATION ACCEPTANCE
    B. EXPERIMENT INTEGRATION
    C. INTEGRATED SYSTEM
    D. CROSSTALK
    E. ELECTROMAGNETIC INTERFERENCE
    F. MASS PROPERTIES
    G. VIBRATION
    H. SHOCK
    I. ACCELERATION
    J. DEPLOYMENT AND STORAGE
    K. THERMAL VACUUM
    L. MAGNETIC PROPERTIES
    M. STORAGE TEMPERATURE

11. DISCREPANCY REPORTS

G. TEST HISTORY CONTINUED

SCIENTIFIC CALIBRATION AT NASA/GSFC

1. MAGNETIC MOMENT
2. MAGNETIC GEOMETRY
3. LINEARITY, RESOLUTION, CROSS COUPLING
4. SHADOWGRAPH
5. LEVEL SENSOR
6. INTERNAL CALIBRATION STEP VALUES
7. OFFSET STEP VALUES
8. FREQUENCY RESPONSE
9. TEMPERATURE DEPENDANCE
10. NONCONFORMANCE REPORTS

H. APOLLO 12 ANOMALIES

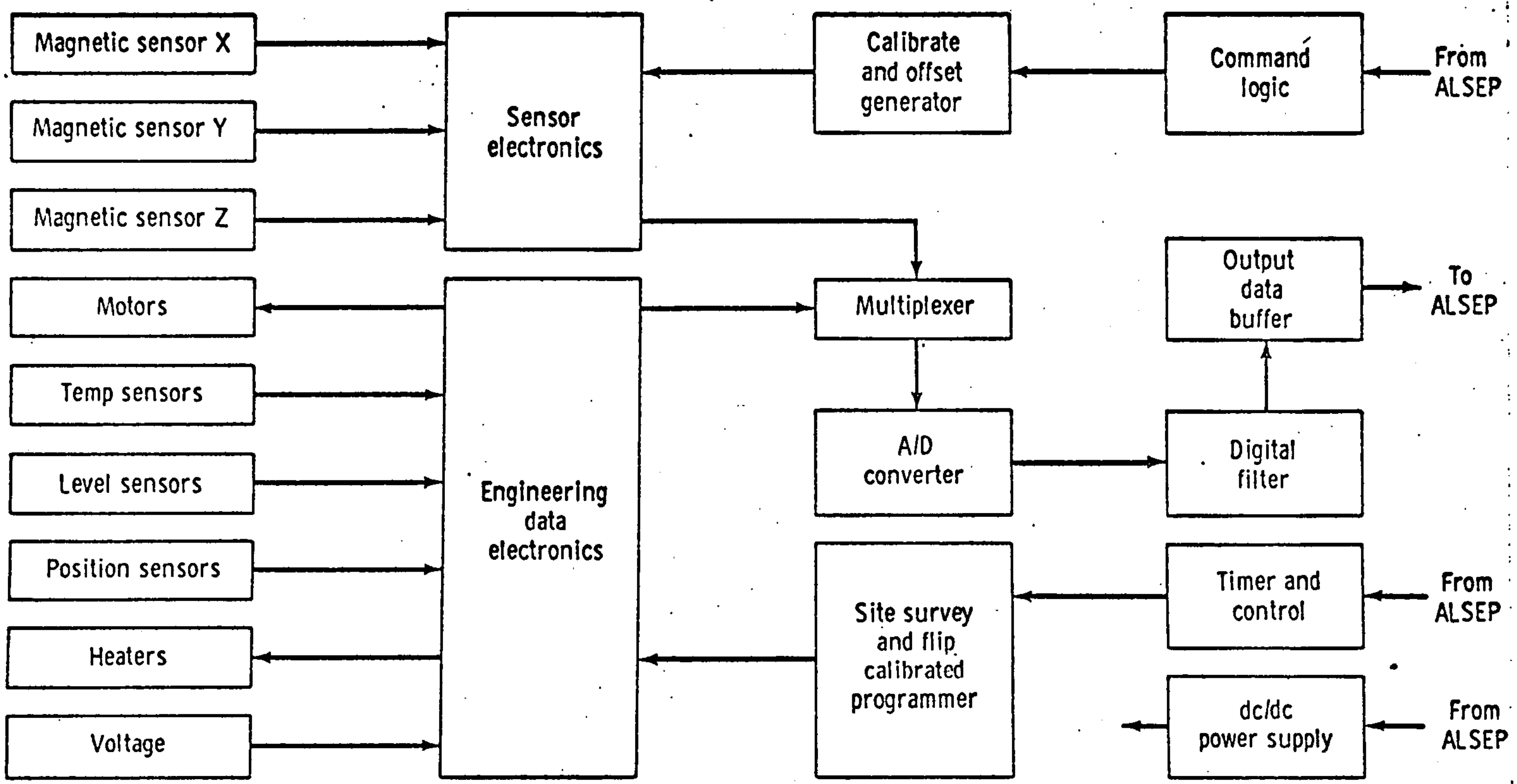
1. DIGITAL FILTER
2. SENSOR AND SENSOR ELECTRONICS
   - A. HIGH TEMPERATURE PROBLEM
   - B. LOW TEMPERATURE PROBLEM

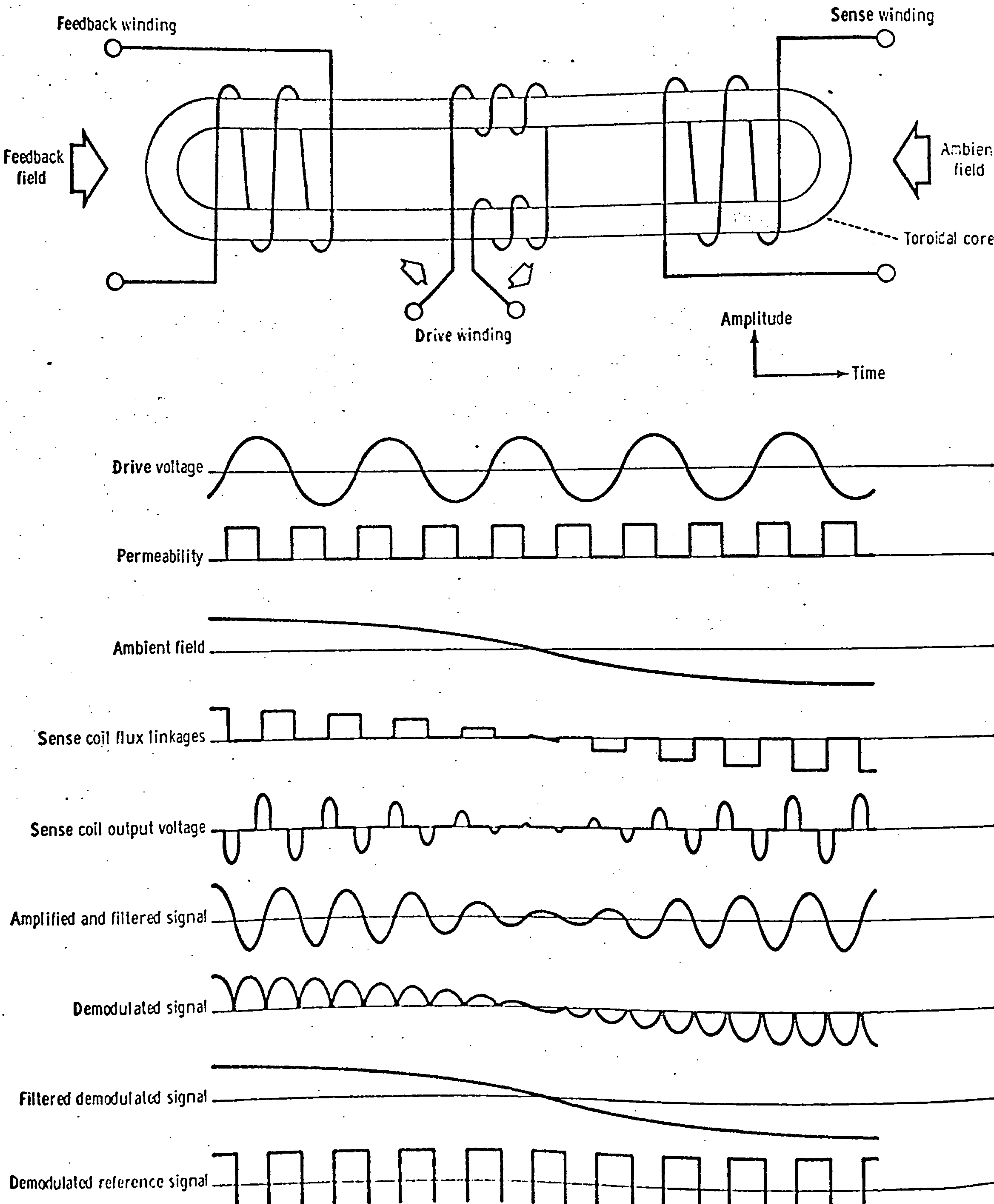
APOLLO 12 MAGNETOMETER CHARACTERISTICS

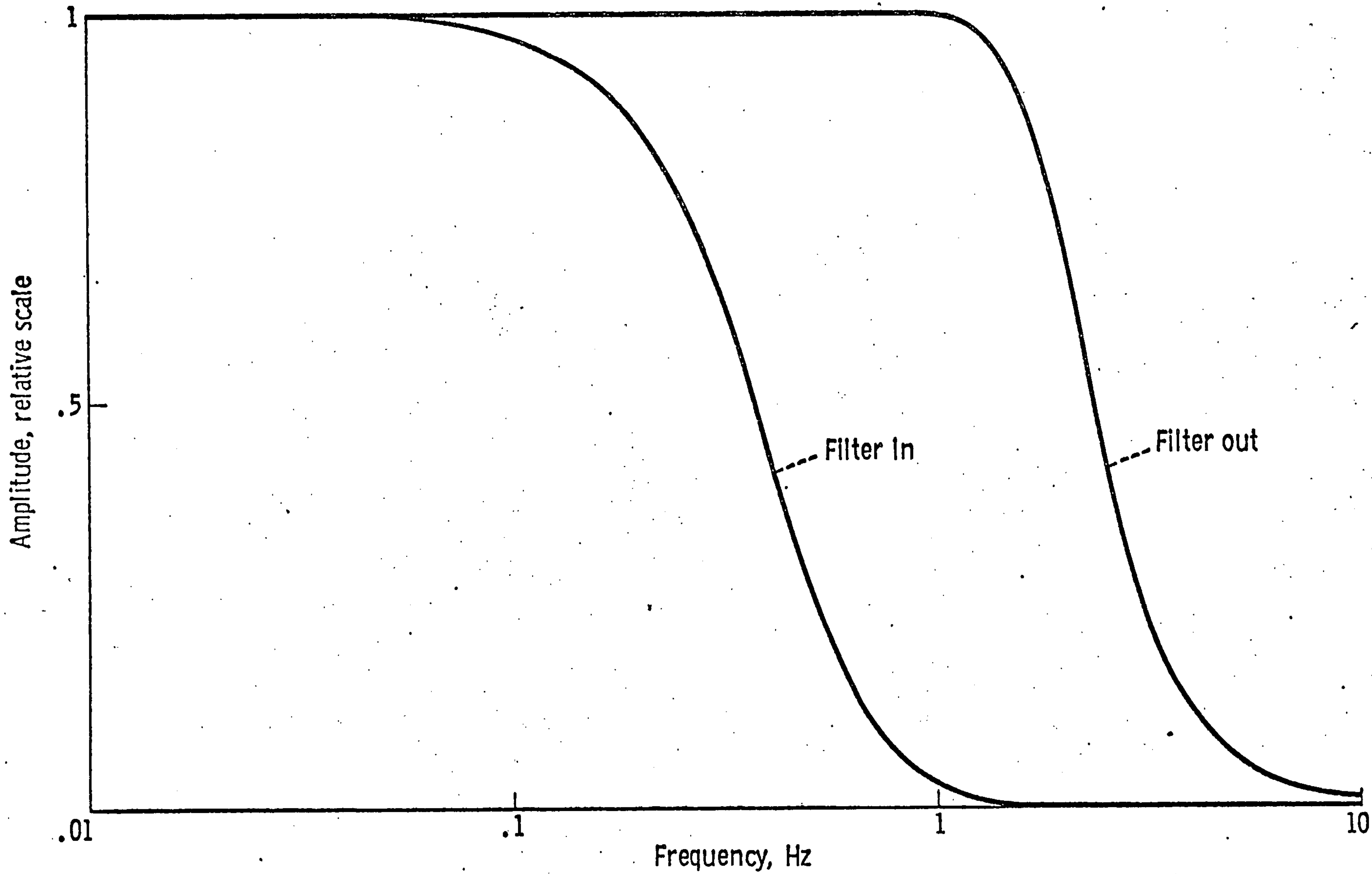
Parameter	Value
Range	0 to ±400 gammas 0 to ±200 gammas 0 to ±100 gammas
Resolution	±0.2 gamma
Frequency response	dc to 2 hertz
Angular response	Proportional to cosine of angle between magnetic-field vector and sensor axis.
Sensor geometry	Three orthogonal sensors at the end of 100-centimeter booms Orientation determination to within 1° in lunar coordinates
Commands	8 ground and 1 spacecraft
Internal calibration and sensor flip	180° flip 0, ±25, ±50, and ±75 percent of full scale
Field bias offset capability	0, ±25, ±50, and ±75 percent of full scale

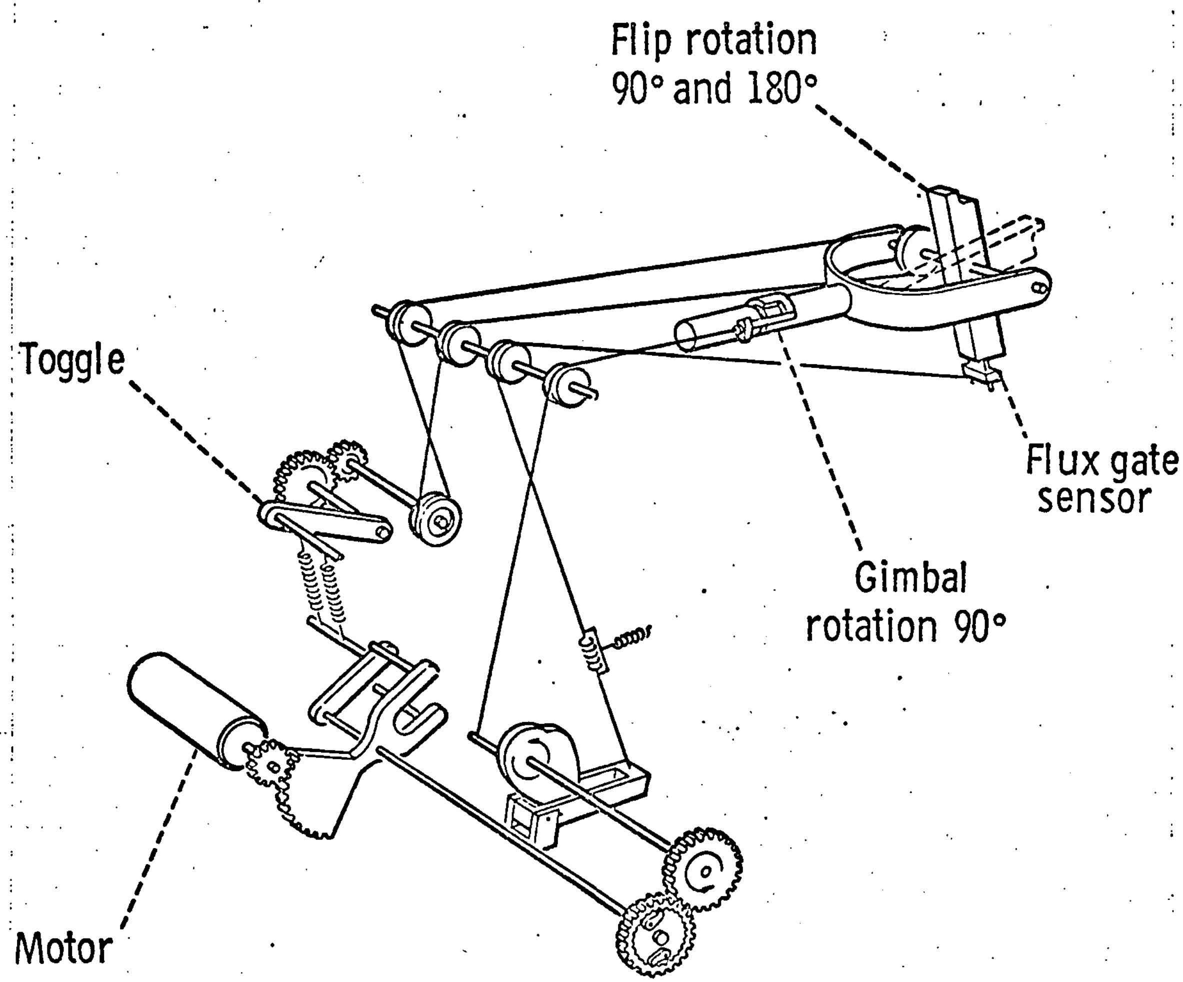
APOLLO 12 MAGNETOMETER CHARACTERISTICS - Concluded

Parameter	Value
Modes of operation	Orthogonal field measurements
	Gradient measurement
	Internal calibration
Power	3.5 watts average in daytime
	7.5 watts average in nighttime
Weight	8.9 kilograms
Size	25 by 28 by 63 centimeters
Operating temperature	-50° to +85° C

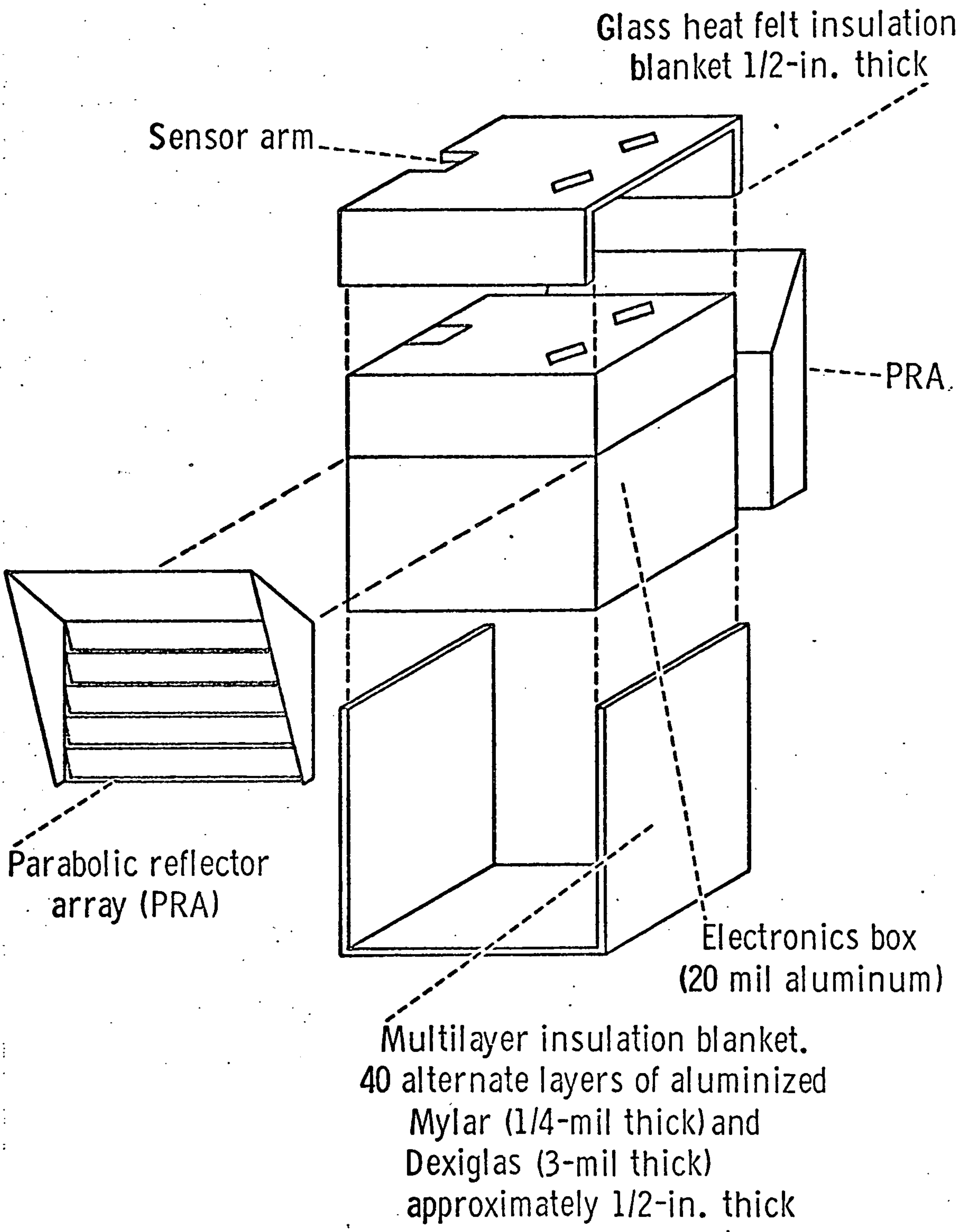

Magnetic sensor X
Magnetic sensor Y
Magnetic sensor Z
Motors
Temp sensors
Level sensors
Position sensors
Heaters
Voltage
Sensor electronics
Engineering data electronics
Calibrate and offset generator
Command logic
From ALSEP
Multiplexer
A/D converter
Site survey and flip calibrated programmer
Output data buffer
To ALSEP
Digital filter
Timer and control
From ALSEP
dc/dc power supply
From ALSEP

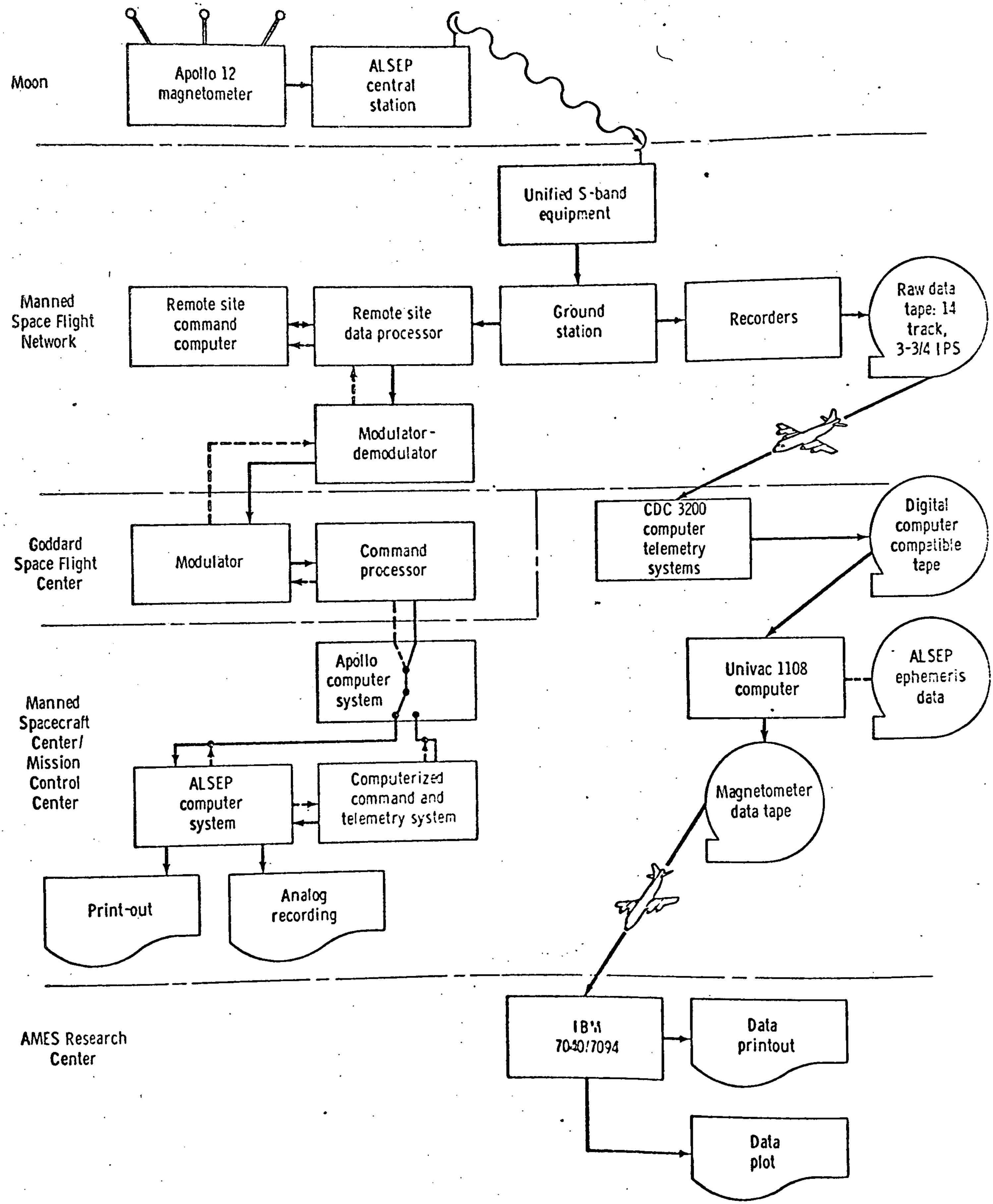

Feedback winding
Sense winding
Feedback field
Ambient field
Toroidal core
Drive winding
Amplitude
Time
Drive voltage
Permeability
Ambient field
Sense coil flux linkages
Sense coil output voltage
Amplified and filtered signal
Demodulated signal
Filtered demodulated signal
Demodulated reference signal


1
.5
Amplitude, relative scale
.01
.1
1
10
Frequency, Hz
Filter in
Filter out



Flip rotation
90° and 180°
Toggle
Flux gate
sensor
Gimbal
rotation 90°
Motor


Glass heat felt insulation
blanket 1/2-in. thick
Sensor arm
PRA
Parabolic reflector
array (PRA)
Electronics box
(20 mil aluminum)
Multilayer insulation blanket.
40 alternate layers of aluminized
Mylar (1/4-mil thick) and
Dexiglas (3-mil thick)
approximately 1/2-in. thick


Moon
Apollo 12 magnetometer
ALSEP central station
Unified S-band equipment
Manned Space Flight Network
Remote site command computer
Remote site data processor
Ground station
Recorders
Raw data tape: 14 track, 3-3/4 IPS
Modulator-demodulator
Goddard Space Flight Center
Modulator
Command processor
CDC 3200 computer telemetry systems
Digital computer compatible tape
Manned Spacecraft Center/ Mission Control Center
Apollo computer system
Univac 1108 computer
ALSEP ephemeris data
ALSEP computer system
Computerized command and telemetry system
Magnetometer data tape
Print-out
Analog recording
AMES Research Center
IBM 7040/7094
Data printout
Data plot

COMMAND LIST

Command	Function
042	Operational power ON
045	Power standby
123	Range select
124	Field offset
125	Offset address
127	Flip-calibrate inhibit
131	Flip-calibrate initiate (Also initiated every 12 hours by the ALSEP timer.)
132	Digital filter bypass
133	Site survey
134	Thermal control

TELEMETRY DATA

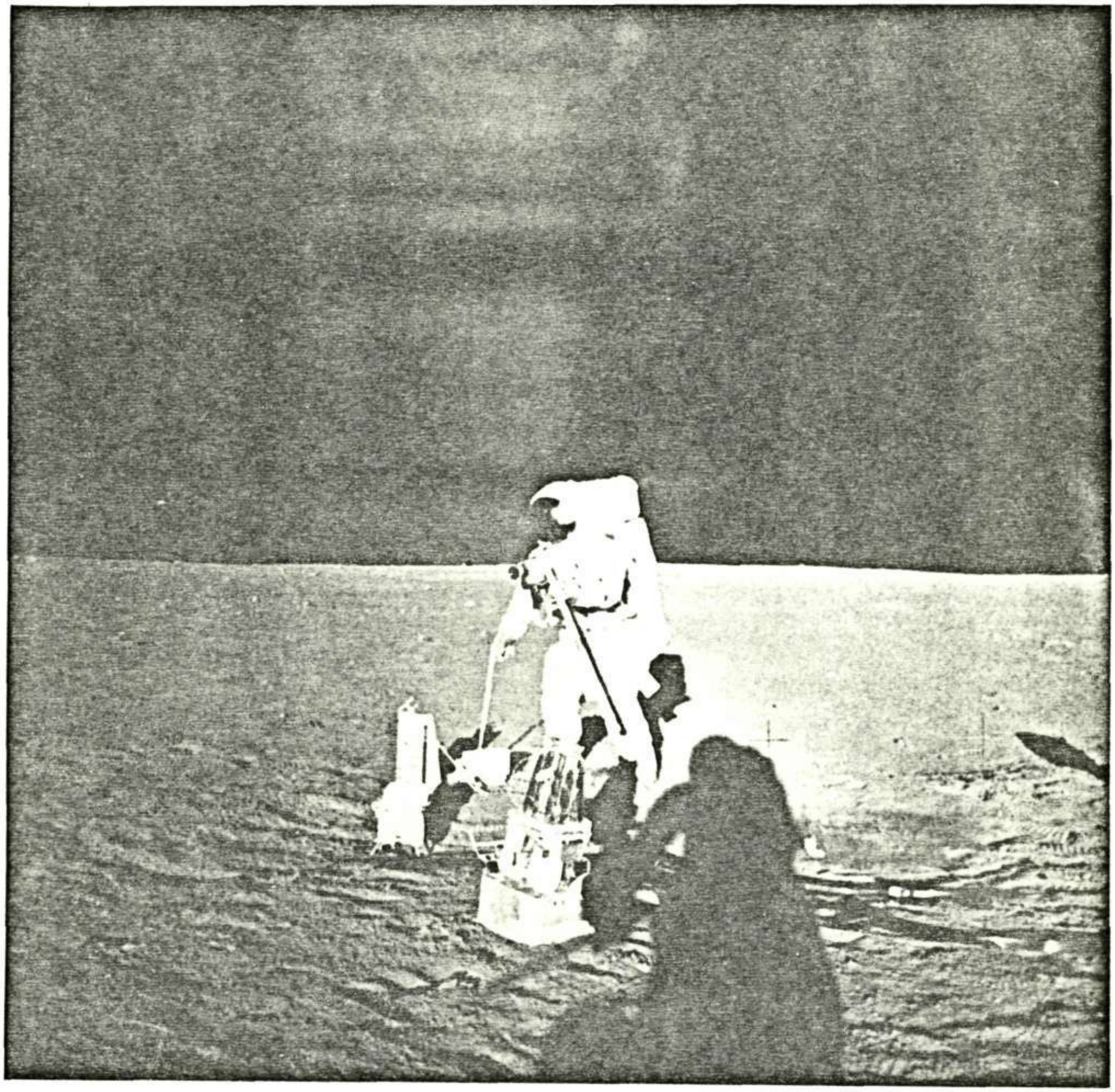
ALSEP word	Subcommutated channel (bit 10)	Engineering analog 7-bit (bits 9 to 3)	Status bits	
			1	2
5	1	X-sensor temperature	X-flip position	X-flip
	2	Y-sensor temperature	Y-flip	Y-flip
	3	Z-sensor temperature	Z-flip	Z-flip
	4	Gimbal flip unit temperature	X-gimbal	Y-gimbal
	5	Electronics temperature	Z-gimbal	Temperature control
	6	Level detector 1	Spare	Heater state
	7	Level detector 2	Range	Range
	8	Reference voltage	Spare	Spare
	9	Same as 1	X-offset	X-offset
	10	Same as 2	X-offset	Y-offset
	11	Same as 3	Y-offset	Y-offset
	12	Same as 4	Z-offset	Z-offset
	13	Same as 5	Z-offset	Z-offset
	14	Same as 6	Address	Address
	15	Same as 7	Filter	Inhibit
	16	Same as 8	Spare	Spare

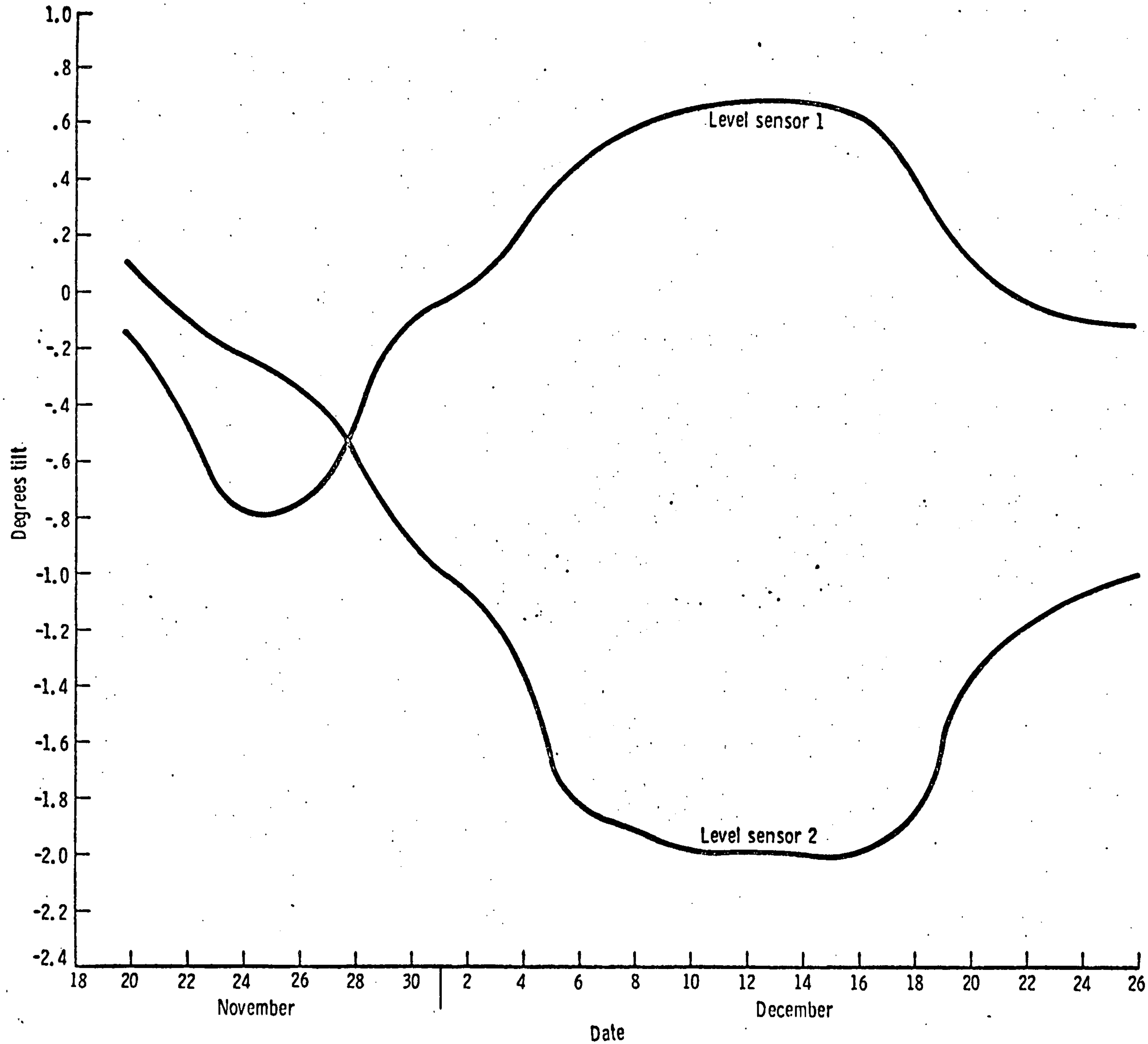
TELEMETRY DATA - Concluded

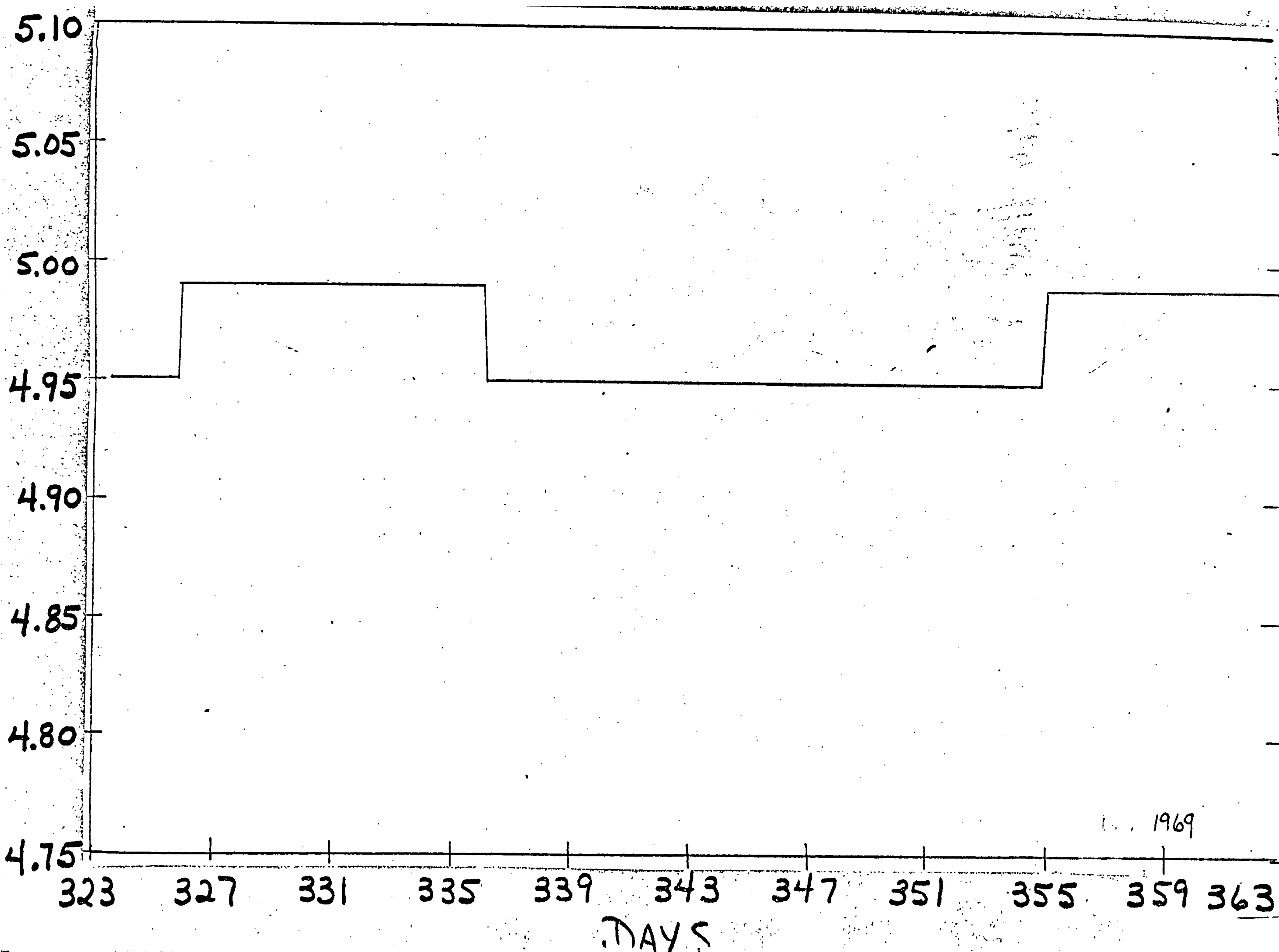
ALSEP word	Subcommutated channel (bit 10)	Engineering analog 7-bit (bits 9 to 3)	Status bits	
			1	2
17	10 bit	X-axis magnetic field		
19	10 bit	Y-axis magnetic field		
21	10 bit	Z-axis magnetic field		
49	10 bit	X-axis magnetic field		
51	10 bit	Y-axis magnetic field		
53	10 bit	Z-axis magnetic field		

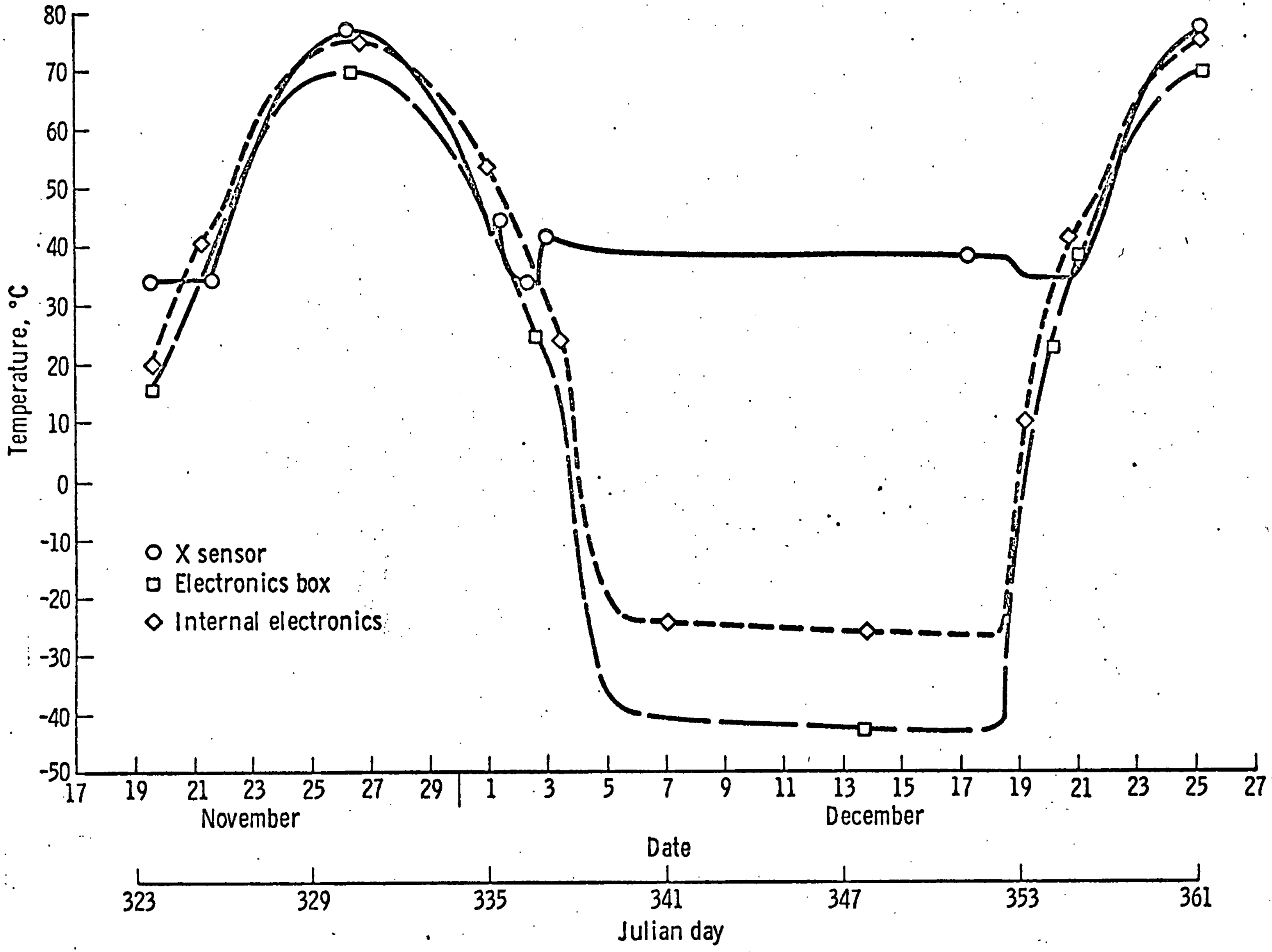
APOLLO 12 MAGNETOMETER EXPERIMENT OPERATIONS

Date	Time (G.m.t.), hr:min	Operation
Nov. 14, 1969	16:22	Lift-off from Kennedy Space Center
Nov. 18, 1969	14:32	Lunar landing
Nov. 19, 1969	12:55	ALSEP removed from lunar module
Nov. 19, 1969	13:41	Magnetometer removed from ALSEP
Nov. 19, 1969	14:01	Magnetometer deployed by Conrad and Bean
Nov. 19, 1969	14:02	Magnetometer photographed
Nov. 19, 1969	14:39	Magnetometer turned ON
Nov. 19, 1969	14:45	Magnetometer range selected
Nov. 20, 1969	11:09	First flip-calibrate sequence completed
Nov. 20, 1969	14:26	Lunar module ascent
Nov. 22, 1969	22:50	Site-survey sequence started




Level sensor 1
Level sensor 2
Degrees tilt
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
-.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
-2.2
-2.4
18
20
22
24
26
28
30
2
4
6
8
10
12
14
16
18
20
22
24
26
November
December
Date

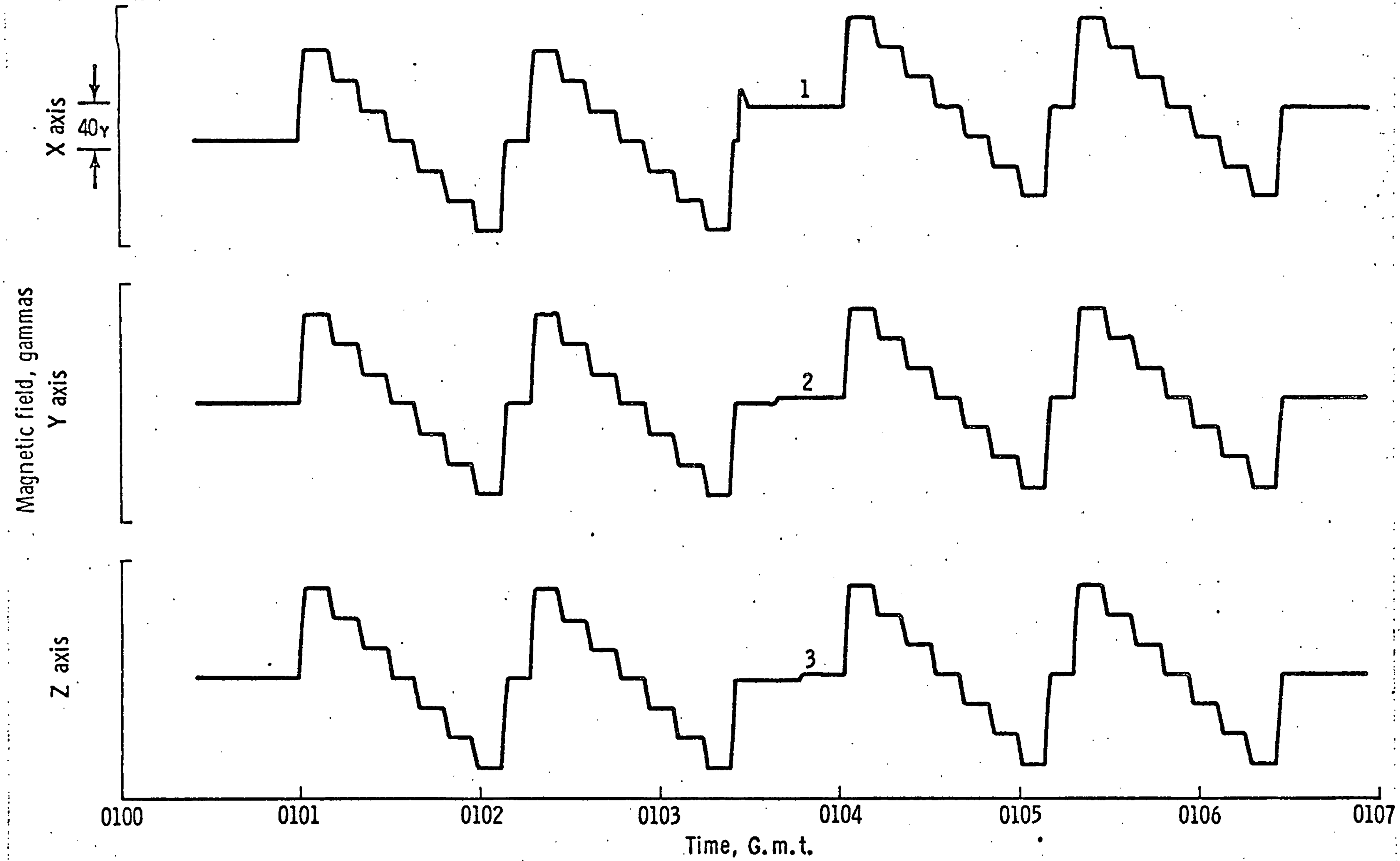

5.10
5.05
5.00
4.95
4.90
4.85
4.80
4.75
1969
323
327
331
335
339
343
347
351
355
359
363
DAYS



Temperature, °C
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
O X sensor
□ Electronics box
◇ Internal electronics
17
19
21
23
25
27
29
1
3
5
7
9
11
13
15
17
19
21
23
25
27
November
December
Date
323
329
335
341
347
353
361
Julian day

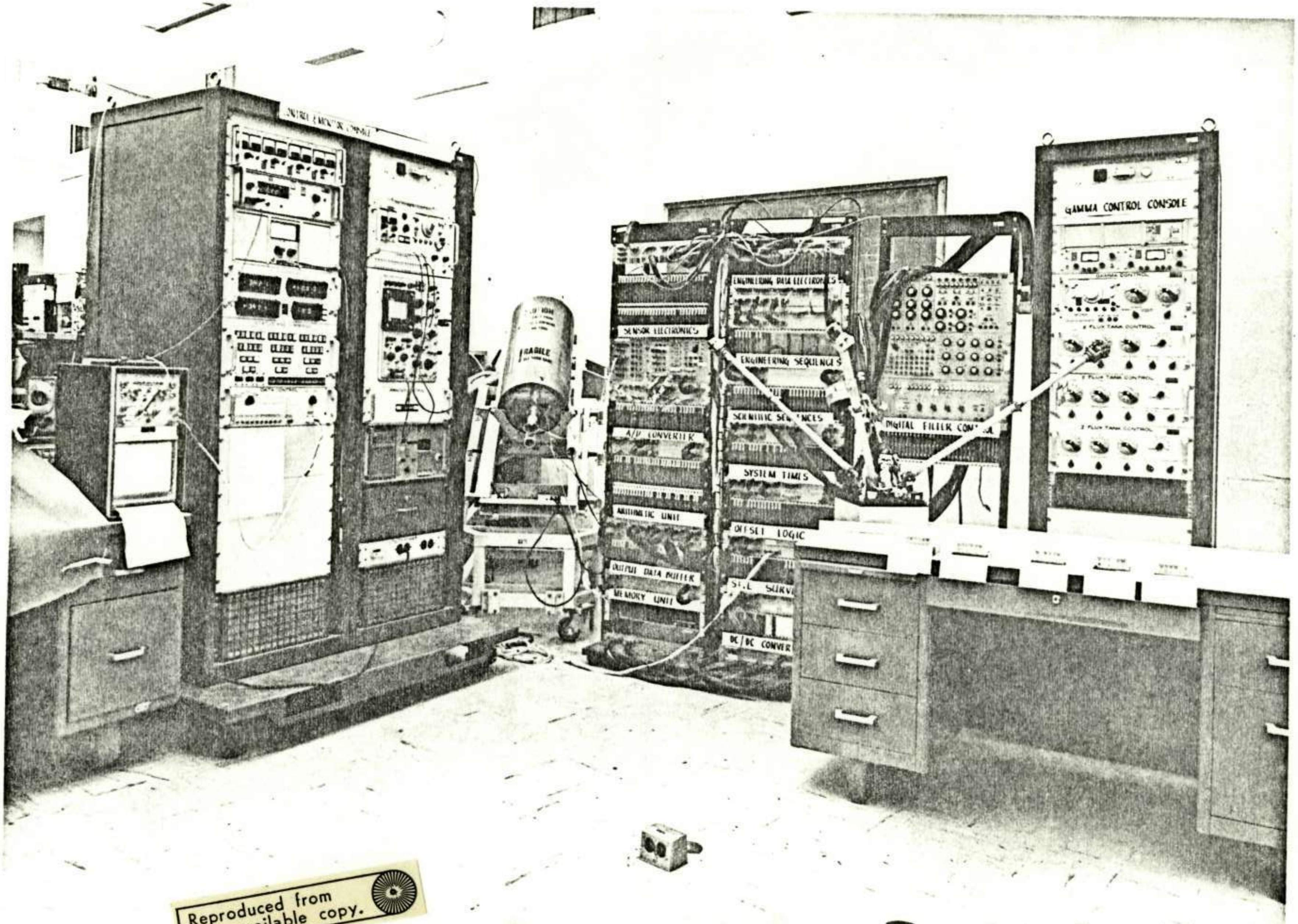
16

[redacted] 12/8/69 [redacted]



17

A-39088



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA

HARDWARE STATUS

	Item	Use	Location
1.	Electrical Brassboard Simulator	Test	Ames
2.	Thermal Model		Ames
3.	Electrical Breadboard	Test	Ames
4.	Engineering Model	Test	Ames
5.	Prototype Model LSM #1	Test	Ames
6.	Qualification Model LSM #2		Philco
7.	Flight Model LSM #6	Apollo 12	Moon
8.	Flight Model LSM #4	Apollo 15	Philco
9.	Flight Model LSM #7	Apollo 15 Spare	Philco
10.	Flight Model LSM #3		Philco
11.	Flight Model LSM #5	Mechanical Complete. Electronics Incomplete	Philco
12.	Human Factors Training Model 1	Apollo 15 training	MSC
13.	Human Factors Training Model 2	Repair	ARC
14.	Ground Support Equipment 1	Tests	ARC
	2	LSM-7	Philco
	3	LSM-7	Philco
	4	LSM-4	Bendix

ELECTRONIC SUBSYSTEM DESIGN

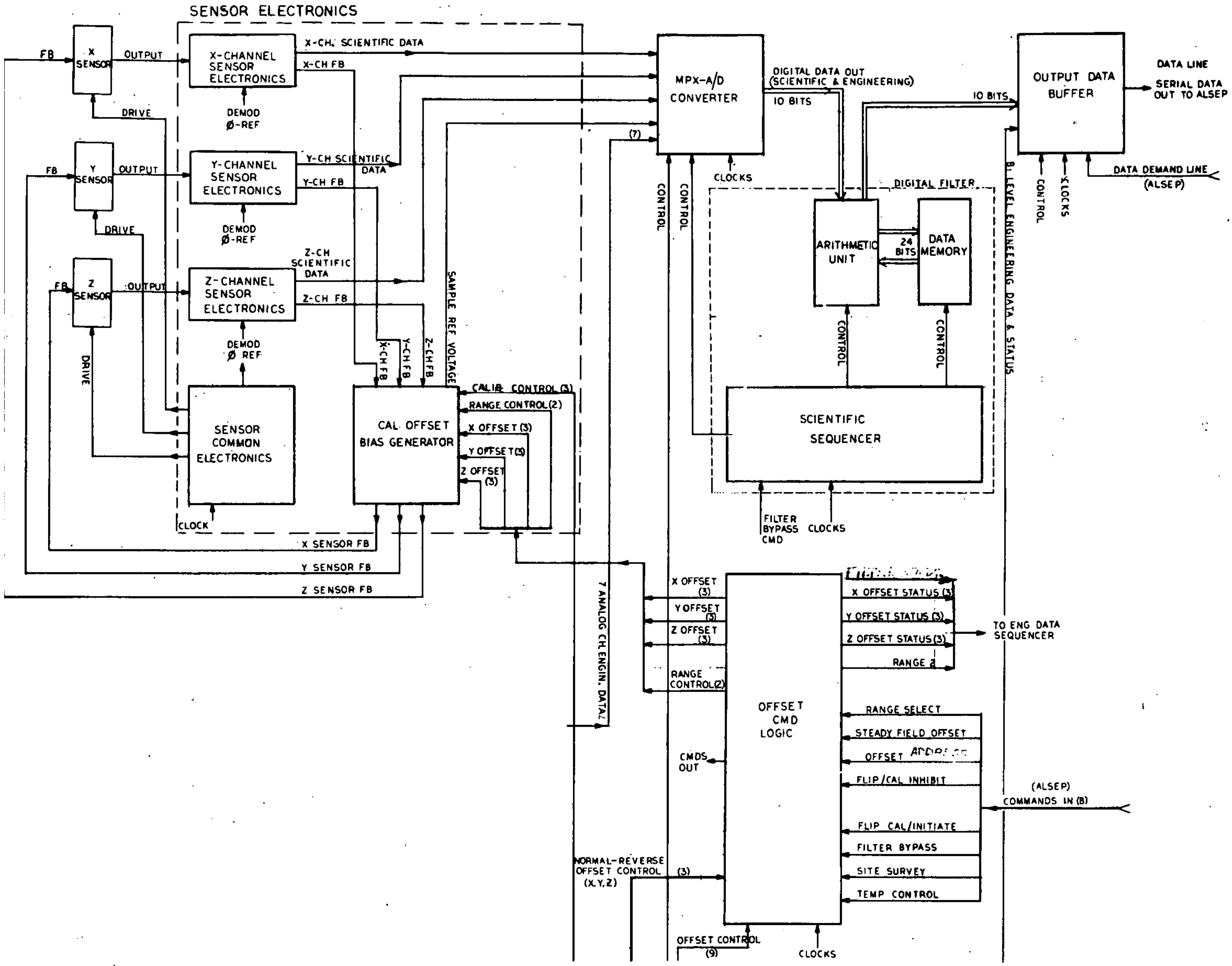
PRIMARY INSTRUMENT PROPERTIES

1.	SENSOR ELEMENTS	Fluxgates (three)
2.	DYNAMIC RANGE	0to $\pm 400\gamma$(nominal; in three linear ranges of $\pm 100\gamma, \pm 200\gamma, \pm 400\gamma$
3.	RESOLUTION	$\pm 0.2\gamma$
4.	FREQUENCY RESPONSE	DC to 0.6 cps
5.	DIGITAL FILTER CHARACTERISTICS	Normalized pole positions $-0.65722 \pm j\ 0.83016$; $-0.90476 \pm j\ 0.27091$
6.	ANGULAR RESPONSE	Proportional to cosine of angle between magnetic field and sensor axis
7.	LONG-TERM ELECTRONIC STABILITY	Drift less than $\pm 0.2\gamma$ in 24-hour period for constant temperature
8.	BIAS OFFSET	0, ±25%, ±50%, and ±75% nominal full scale
9.	CALIBRATION RASTER	+ and -0, 25%, 50%, and 75% of nominal full scale
10.	SENSOR GEOMETRY	(a) Three orthogonal axes 40 inches long (b) 60 inches between sensors and 26 inches off lunar surface (c) Orientation determination using biaxial level sensor and shadowgraph to within 1 degree of lunar coordinates
11.	VERTICAL COMPONENT OF CURL $\vec{H}$	1×10^{-8} amp/cm^2 minimum sensitivity
12.	POWER	3.5 watts average nominal scientific operation. (See section 3.3.4 for further details.)

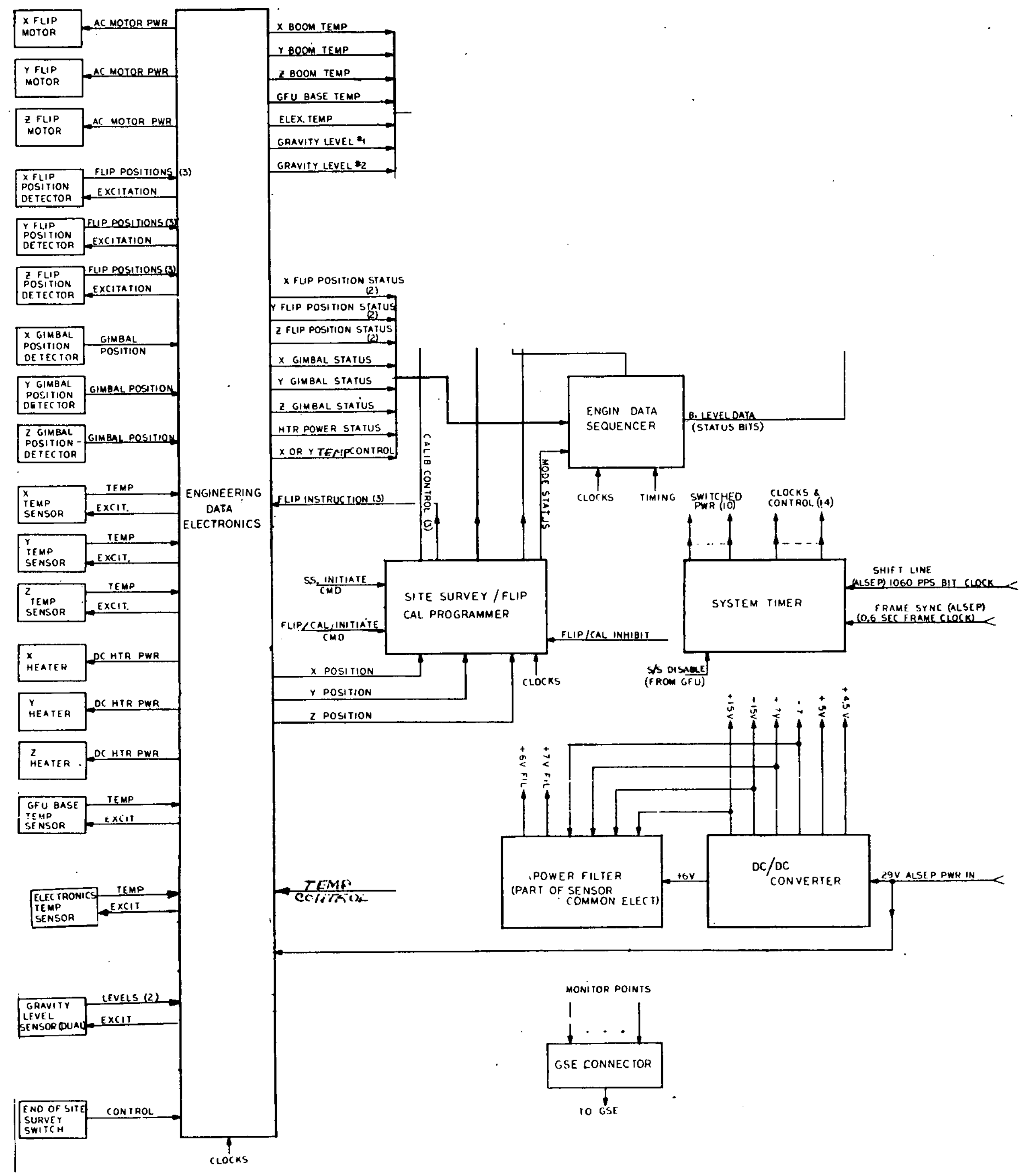
PRIMARY INSTRUMENT PROPERTIES (CONTINUED)

13. WEIGHT	Less than 18 pounds. (See section 3.3.2 for further details.)
14. SIZE	Approximately 10" x 11" x 25" in folded ALSEP configuration.
15. TEMPERATURE RANGE	Operating: $-30^{o}C$ to $+65^{o}C$.
16. LIFE	1 year reliability goal of 0.99
17. MODES OF OPERATION	(a) Scientific X, Y, Z orthogonal measurements (b) Site survey of magnetic field gradients (c) Internal calibration
18. COMMAND CAPABILITY	Both internal and ground commands
19. ENGINEERING READOUTS	Temperature, voltage, orientation
20. MAGNETIC CLEANLINESS	$\approx 2\gamma$ at sensor positions

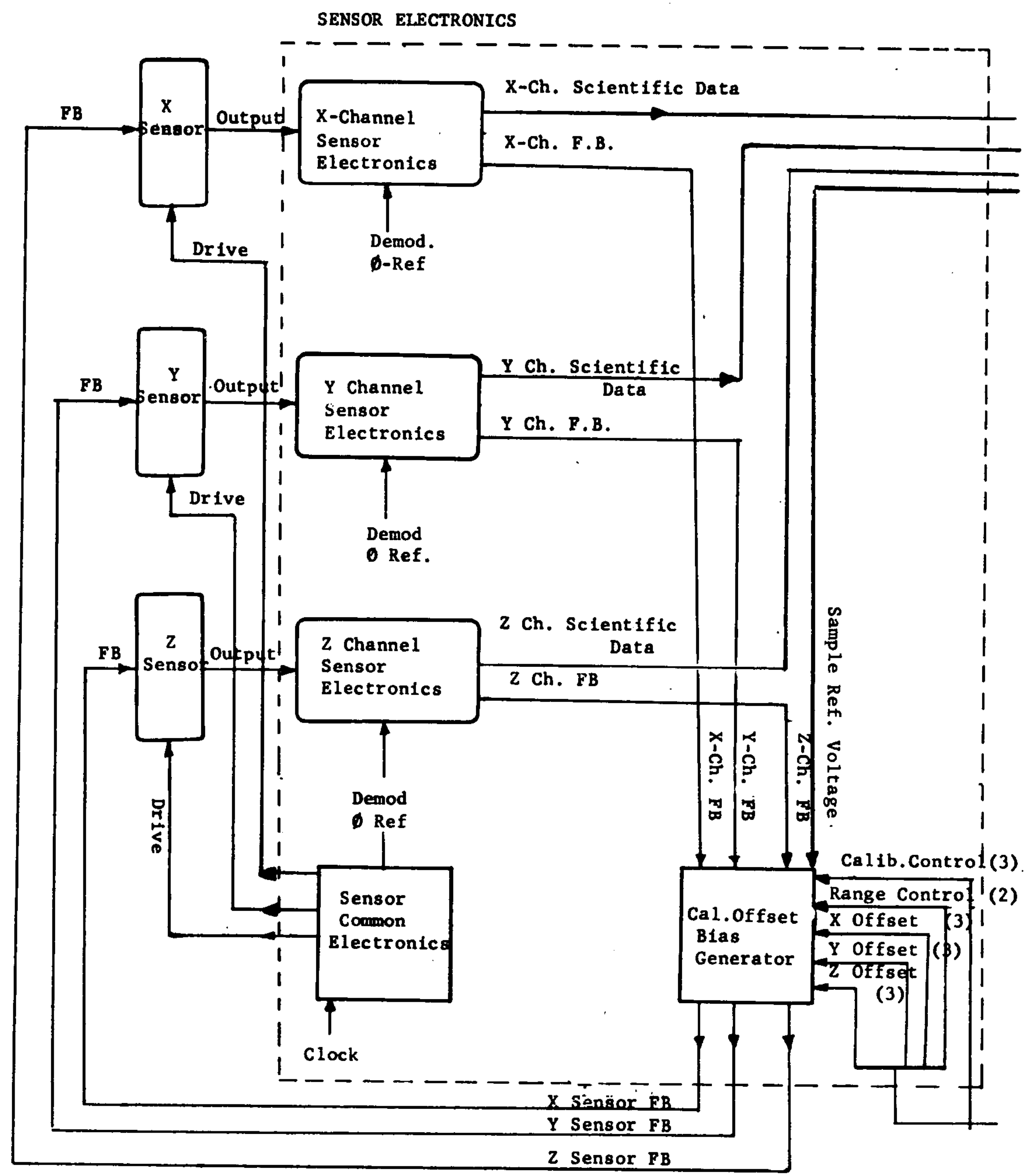
FUNCTIONAL BLOCK DIAGRAM – MEASUREMENT FUNCTION



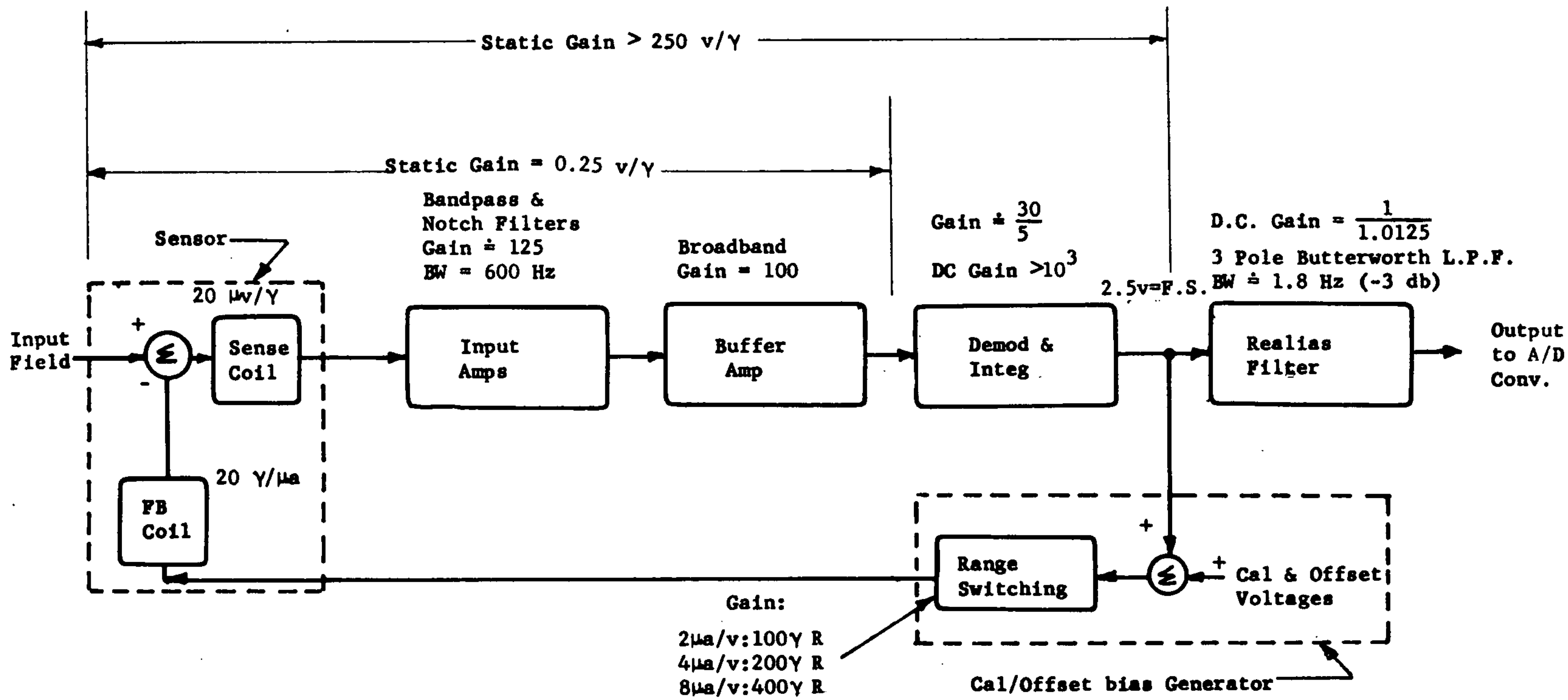
FUNCTIONAL BLOCK DIAGRAM – HOUSEKEEPING/OPERATIONS



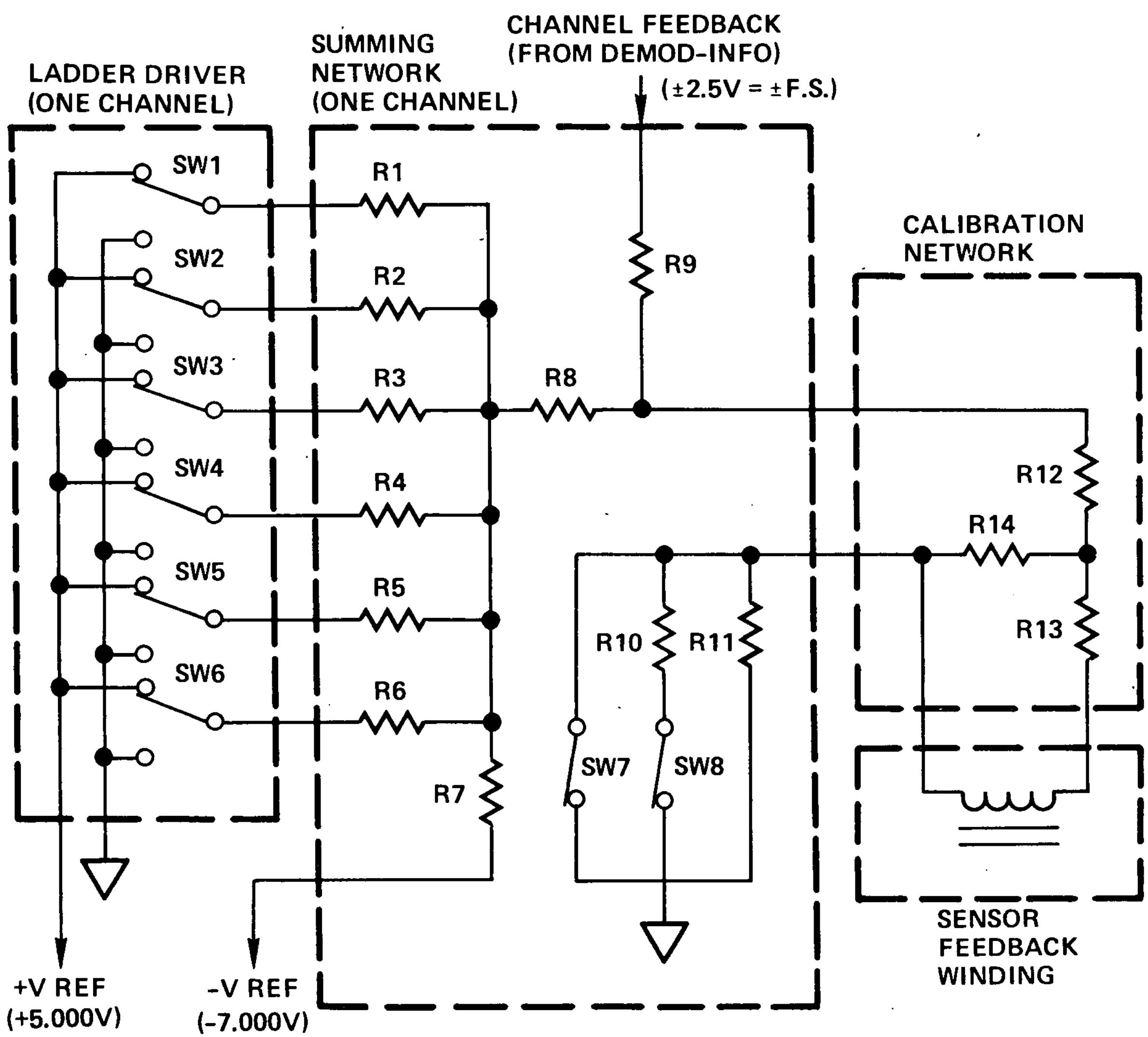
SENSOR ELECTRONICS BLOCK DIAGRAM



SENSOR CHANNEL ELECTRONICS



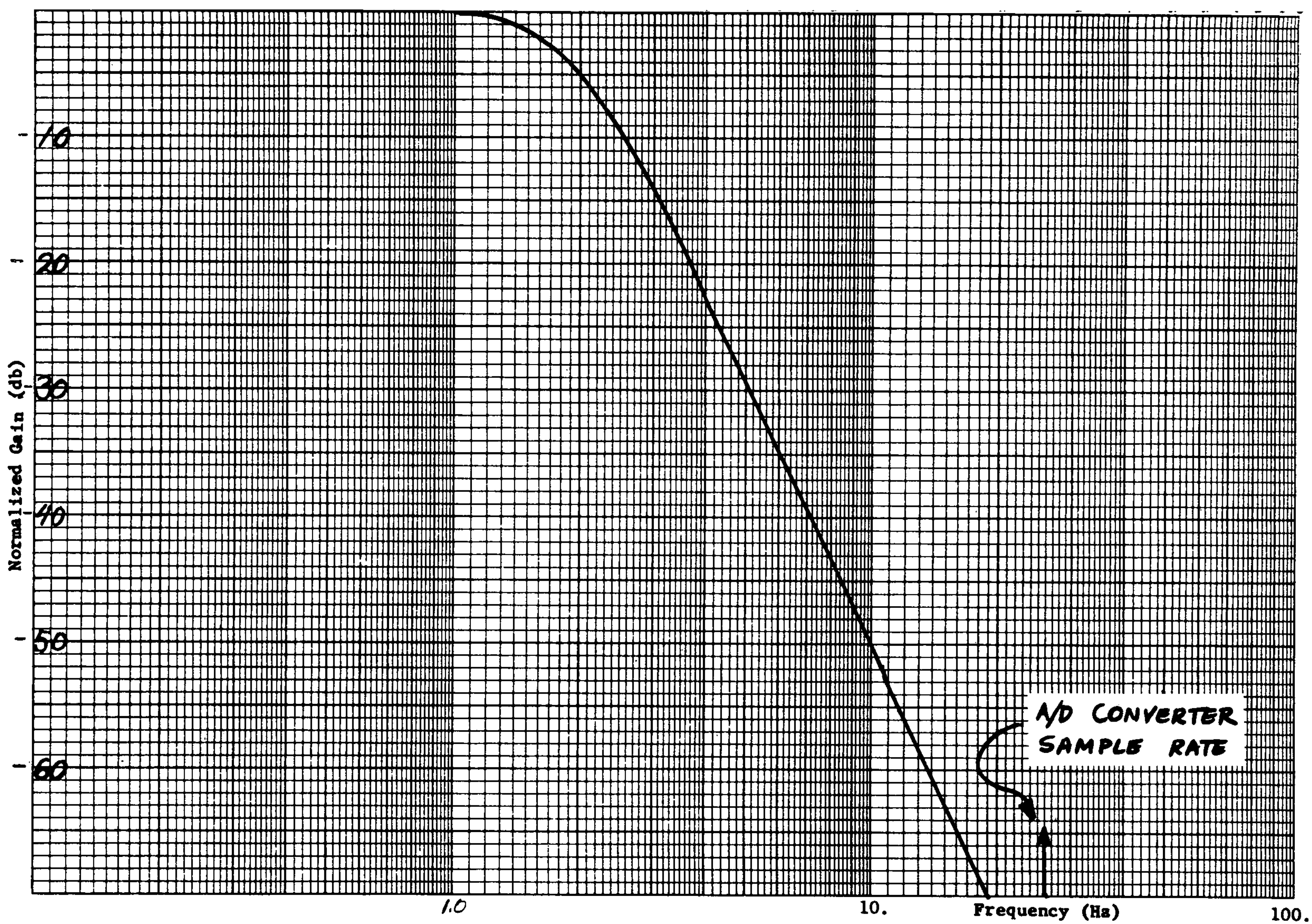
CAL-OFFSET BIAS GENERATION



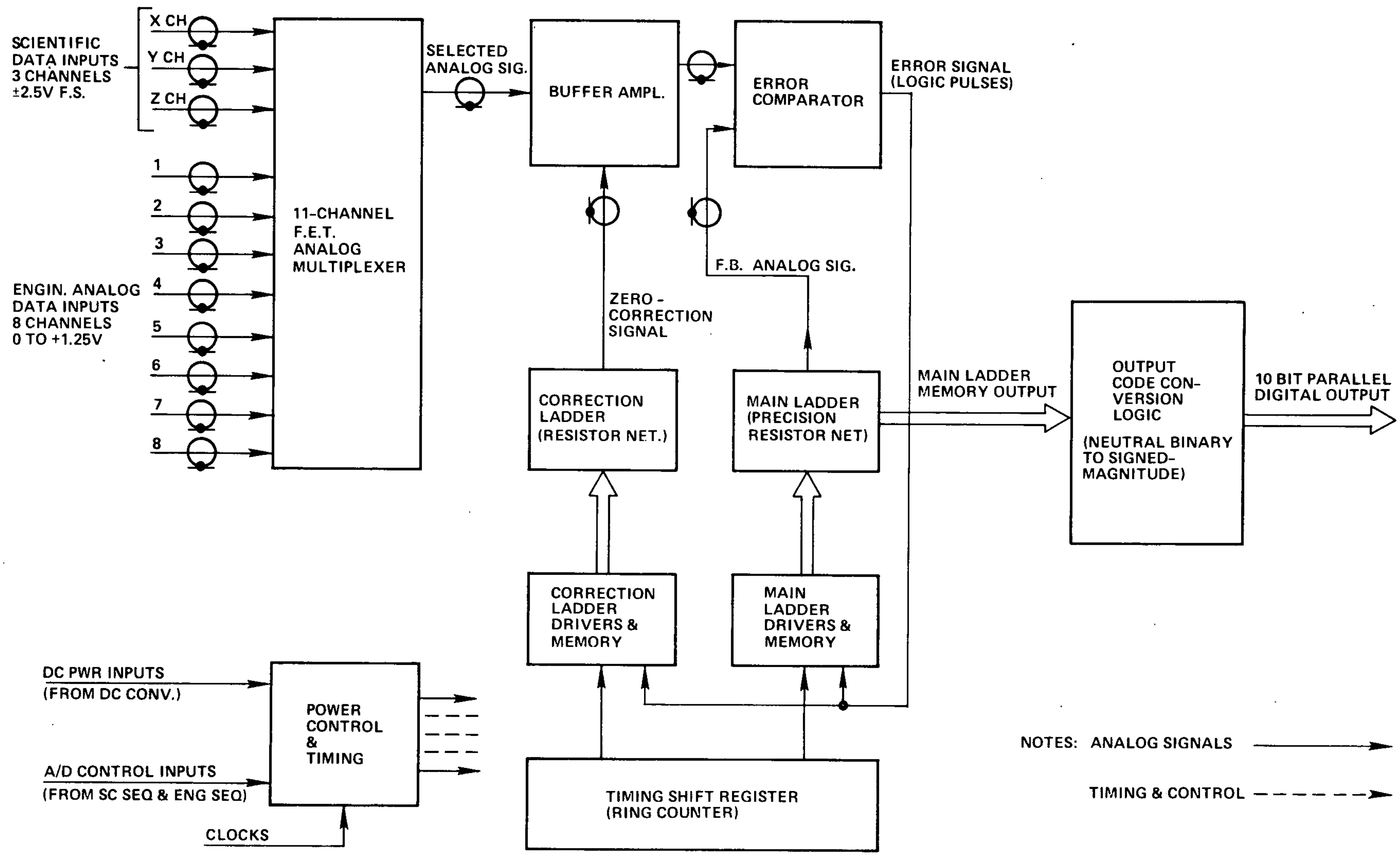
R1 = CAL MSB RES. = 125K, WW
R2 = CAL BIT 2 RES. = 250K, WW
R3 = CAL LSB RES. = 500K, WW
R4 = OFFSET MSB RES. = 125K, WW
R5 = OFFSET BIT 2 RES. = 250K, WW
R6 = OFFSET LSB RES. = 500K, WW
R7 = REF. BIAS RES., WW
R8, R9 = SCALING RES., WW
R10 = 200γ RANGE RES., WW
R11 = 100γ RANGE RES., WW
R12 = SAT, IMPEDANCE EQUALIZER, MF
R13 = IMPEDANCE SET, WW
R14 = SAT, GAIN ADJUST., MF

SW1 = CAL MSB LADDER SWITCH
SW2 = CAL BIT 2 LADDER SWITCH
SW3 = CAL LSB LADDER SWITCH
SW4 = OFFSET MSB LADDER SWITCH
SW5 = OFFSET BIT 2 LADDER SWITCH
SW6 = OFFSET LSB LADDER SWITCH
SW7 = 400γ RANGE SWITCH
SW8 = 200γ RANGE SWITCH

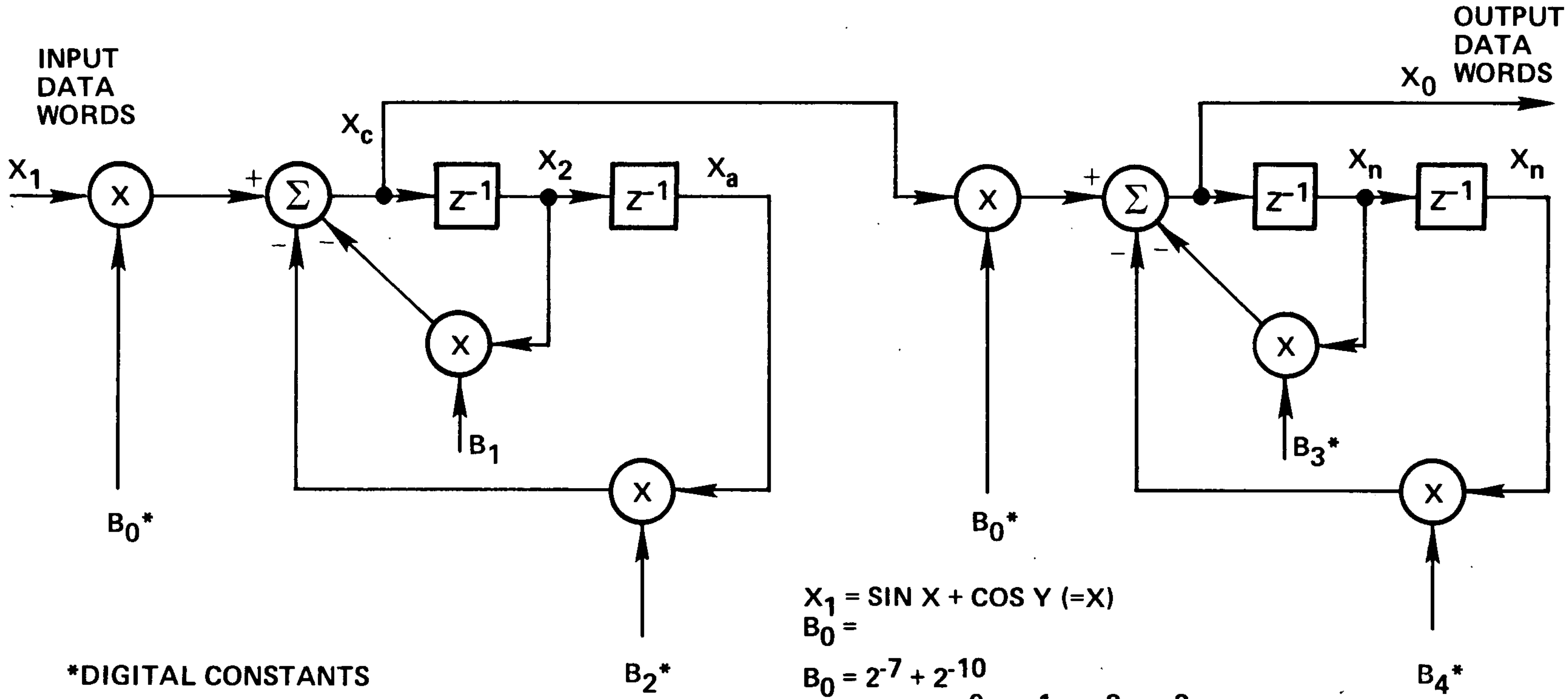
PRE–ALIAS FILTER RESPONSE



A/D CONVERTER BLOCK DIAGRAM



DIGITAL FILTER MATHEMATICAL FUNCTIONAL BLOCK DIAGRAM

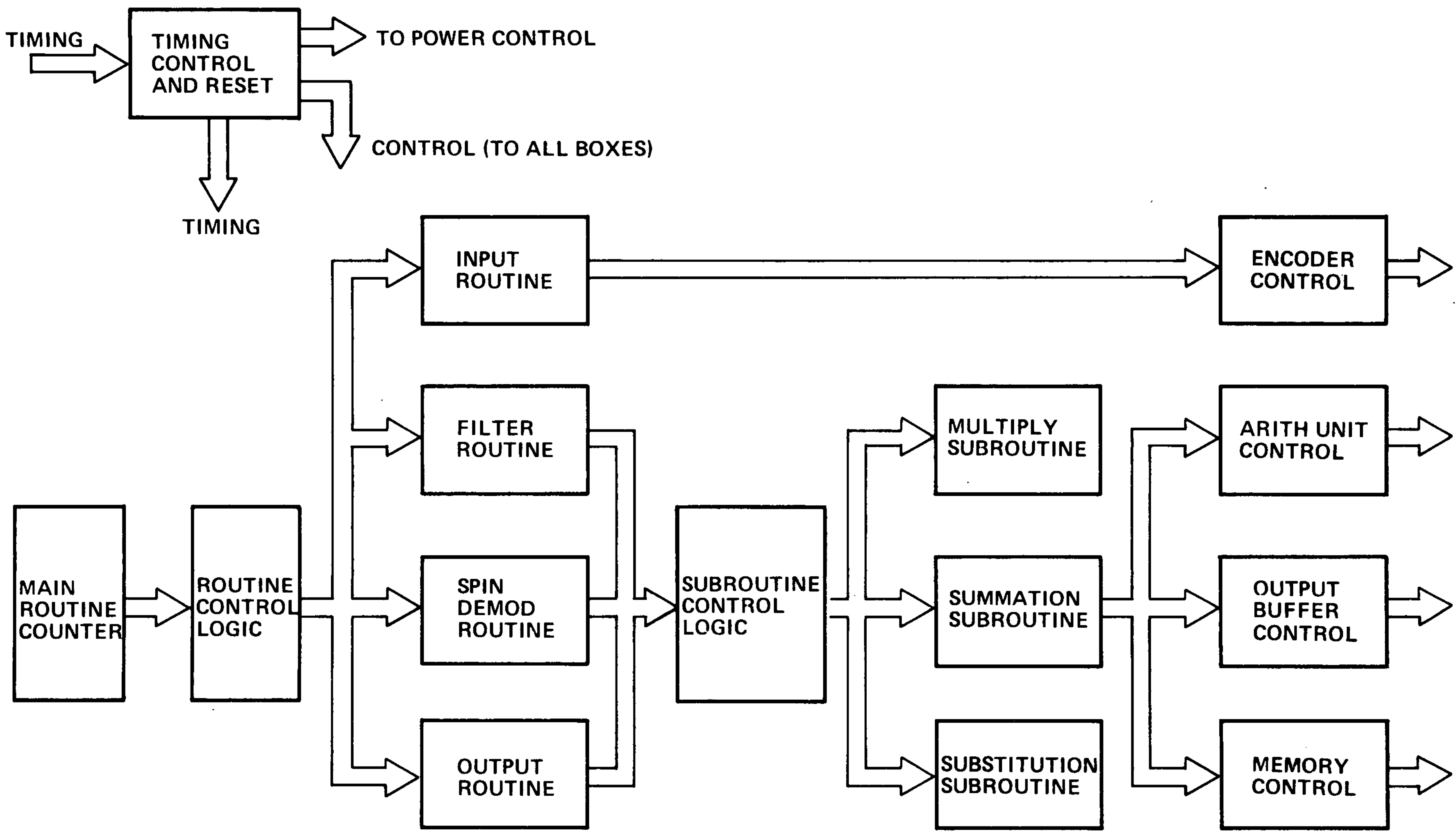


*DIGITAL CONSTANTS

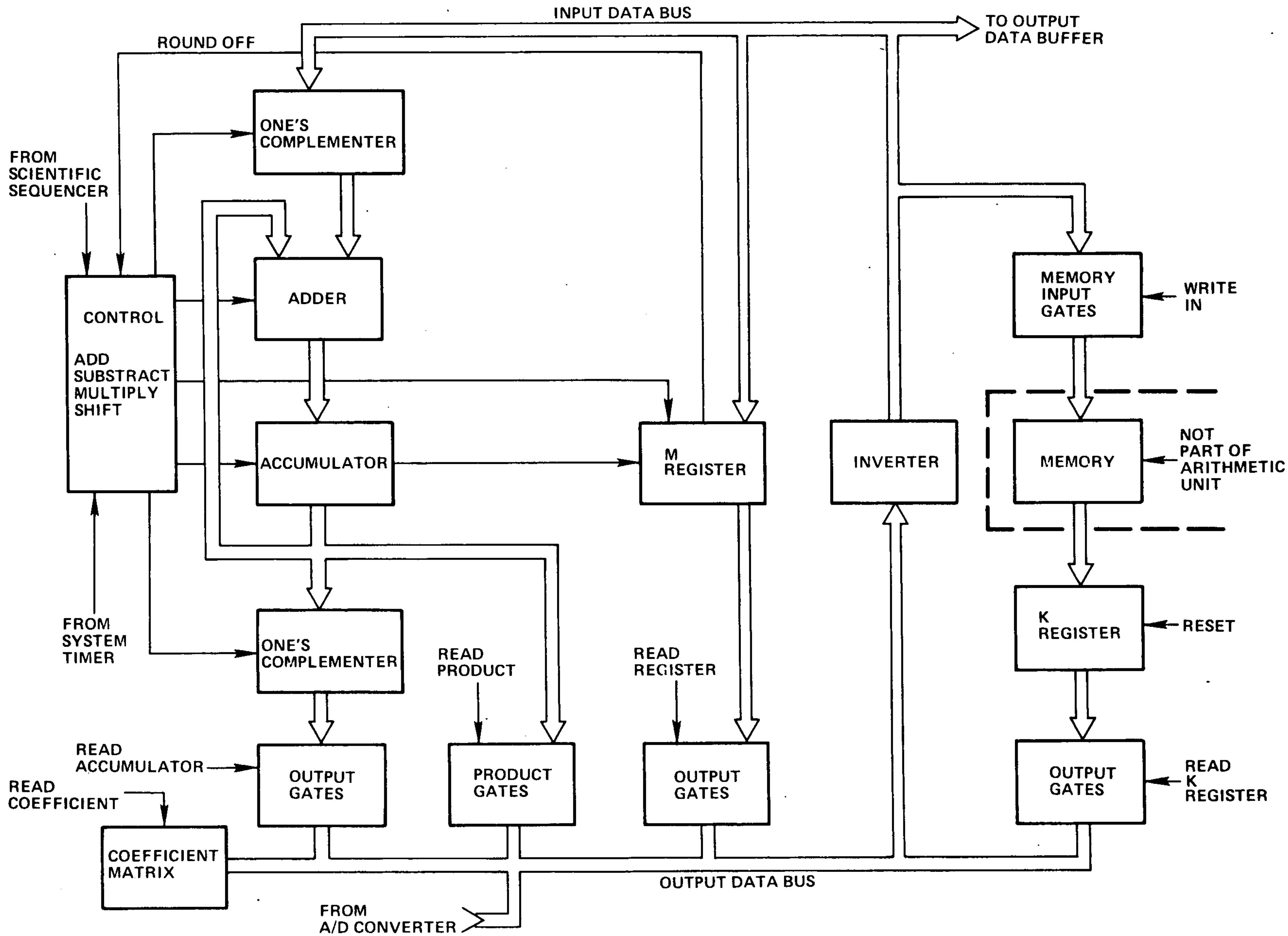
X_1 = SIN X + COS Y (=X)
B_0 =

$B_0 = 2^{-7} + 2^{-10}$
B_1 = SGN. $+2^{0} + 2^{-1} + 2^{-2} + 2^{-3}$
$B_2 = 2^{-1} + 2^{-2} + 2^{-3} + 2^{-7} + 2^{-9}$
B_3 = SIGN. $+ 2^{0} + 2^{-1} + 2^{-2} + 2^{-4} + 2^{-6}$

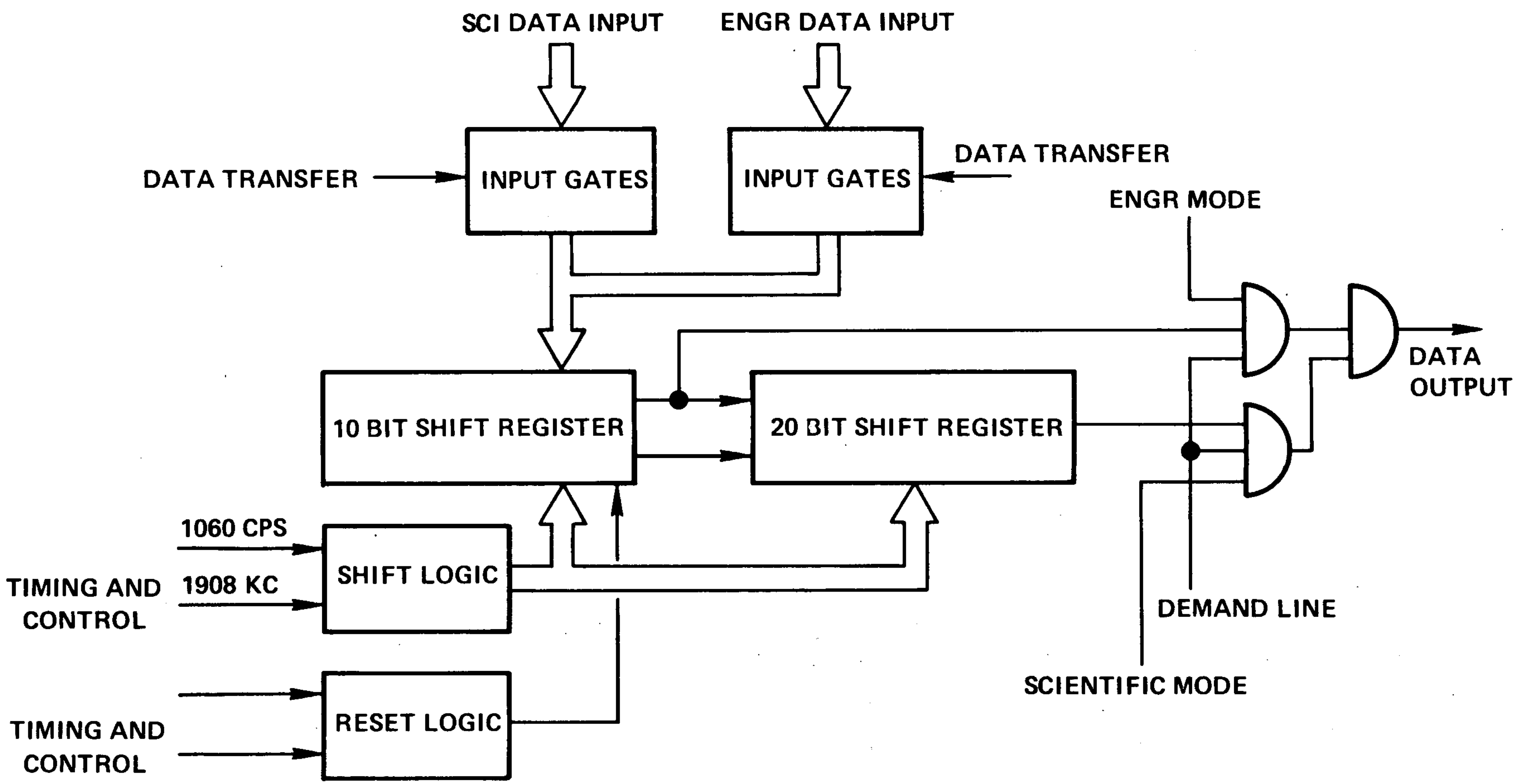
SEQUENCER FLOW DIAGRAM



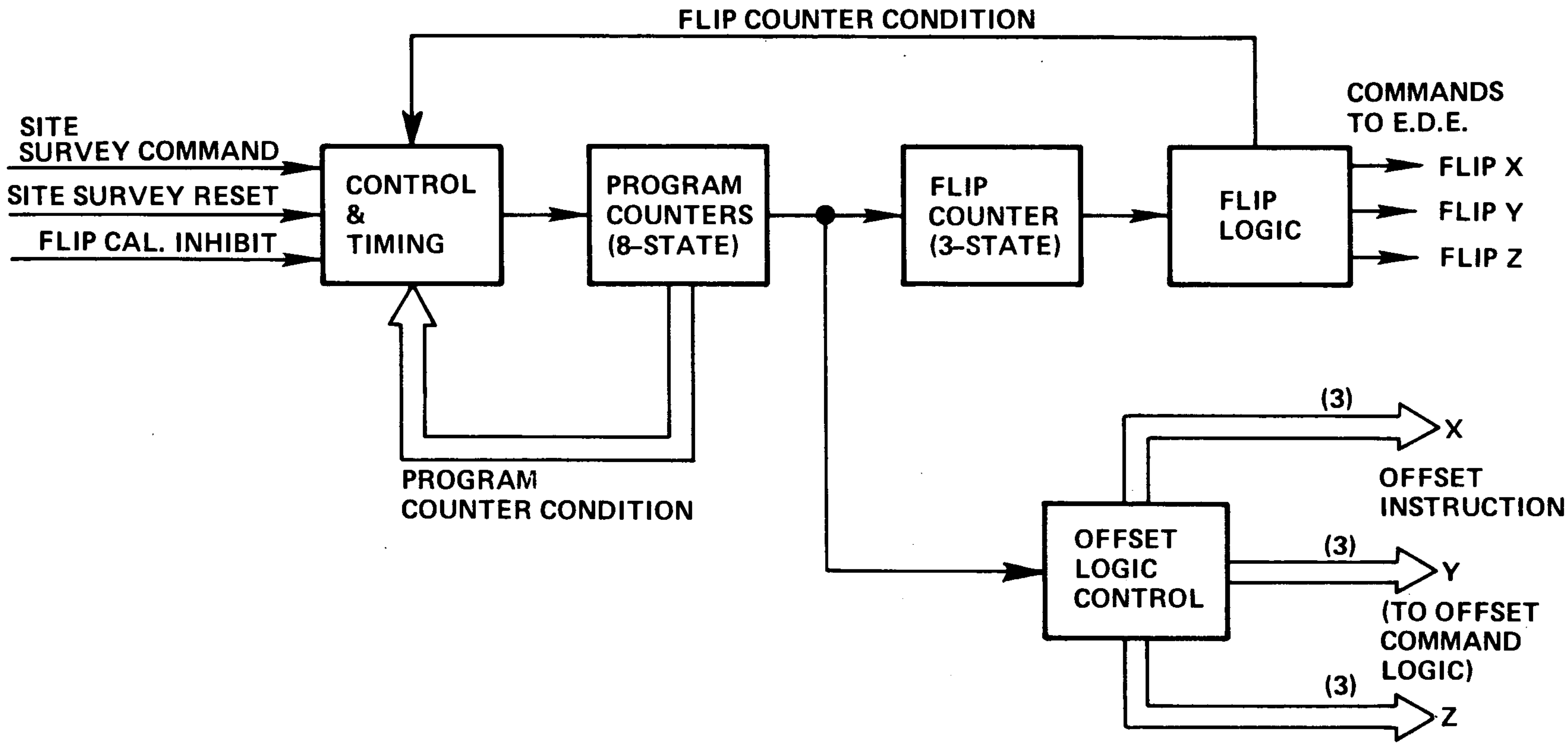
ARITHMETIC UNIT BLOCK DIAGRAM



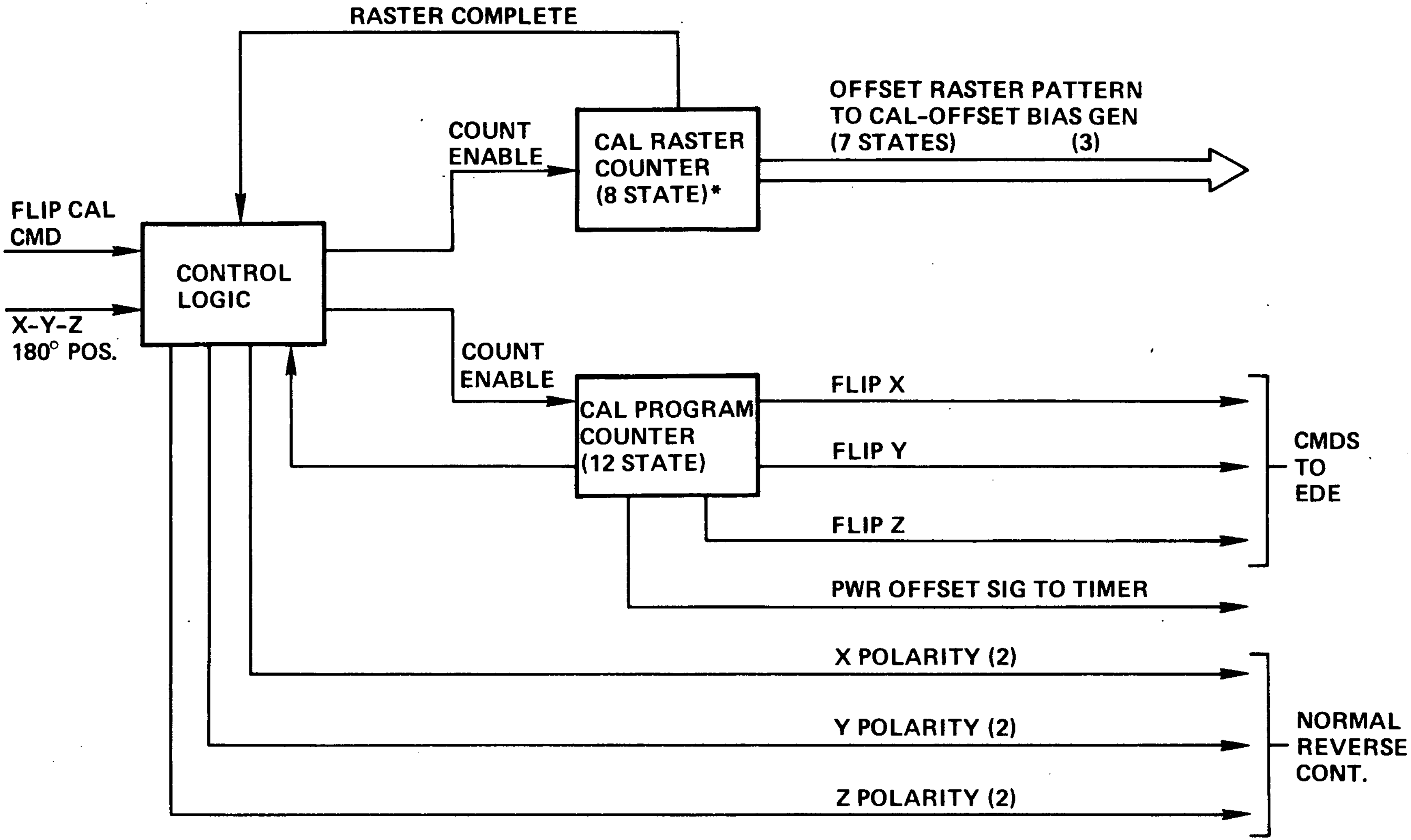
OUTPUT DATA BUFFER FUNCTIONAL DIAGRAM



SITE SURVEY PROGRAMMER



FLIP-CAL PROGRAMMER



*COUNTER HAS 8 STATES WITH 7 UNIQUE OUTPUTS

POSITION DETECTOR BLOCK DIAGRAM

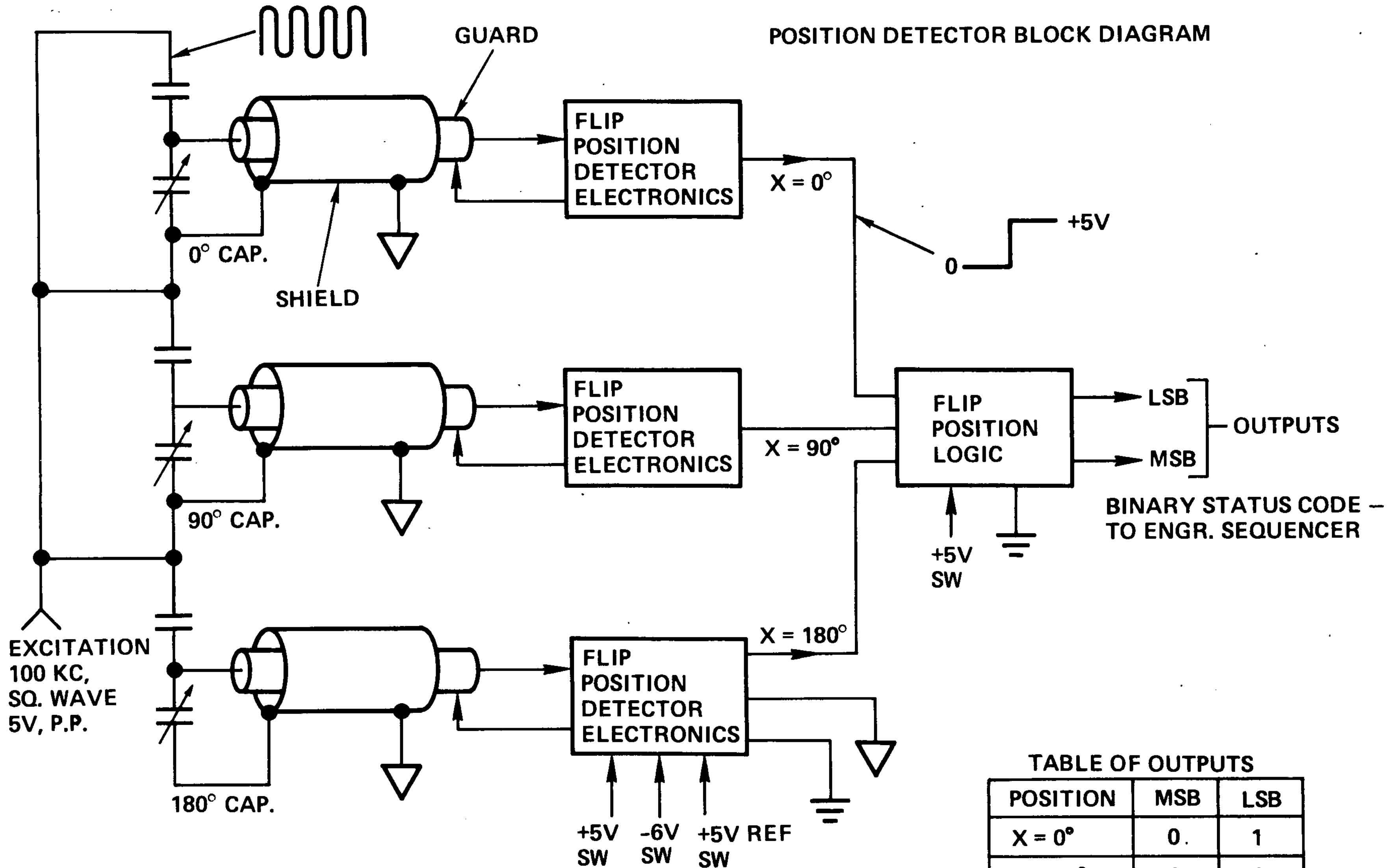


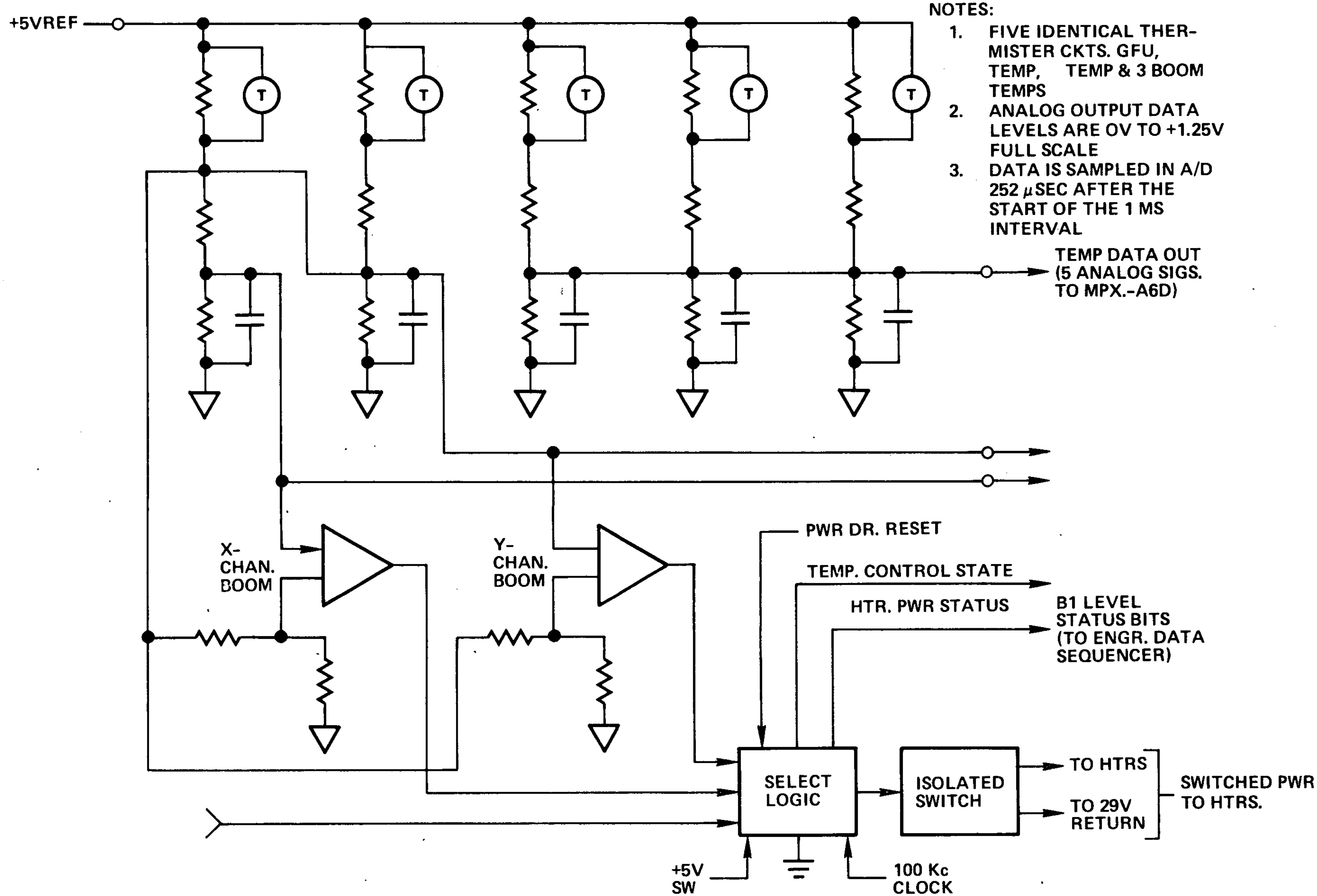
TABLE OF OUTPUTS

POSITION	MSB	LSB
X = 0°	0	1
X = 90°	1	0
X = 180°	1	1
NEITHER	0	0

NOTES:

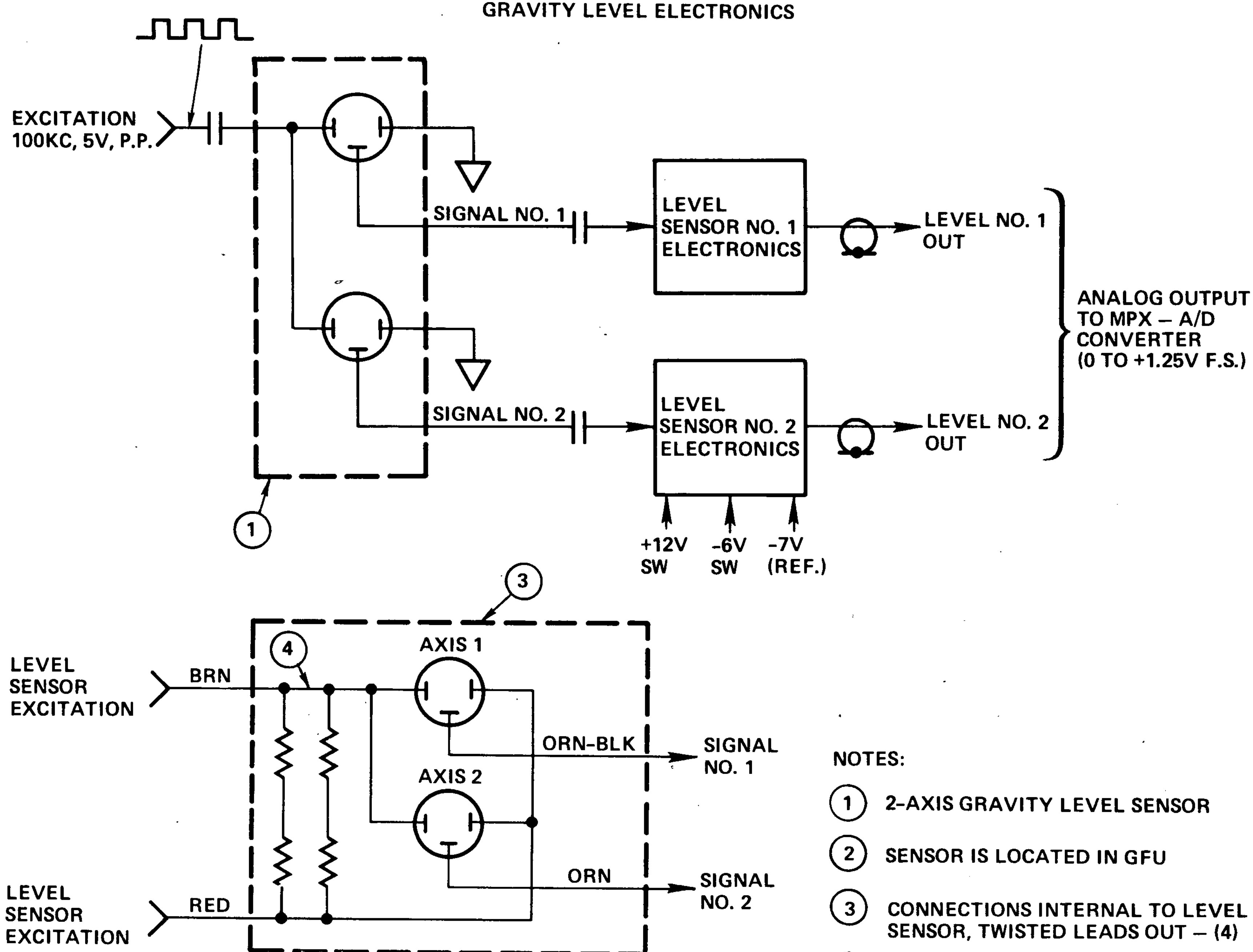
1. WHEN MAGNETOMETER IS ON THE POSITION, THE OUTPUT OF THE DETECTOR ELECTRONICS IS +5V(="1)
2. THE SYMBOL ⏚ IS DIGITAL GROUND; ▽ IS ANALOG GROUND
3. ALL VOLTAGES ARE ON FOR 1MSEC, ONCE PER TLM FRAME

TEMPERATURE MONITORS AND HEATER CONTROL



NOTES:
1. FIVE IDENTICAL THERMISTER CKTS. GFU, TEMP, TEMP & 3 BOOM TEMPS
2. ANALOG OUTPUT DATA LEVELS ARE OV TO +1.25V FULL SCALE
3. DATA IS SAMPLED IN A/D 252 μSEC AFTER THE START OF THE 1 MS INTERVAL

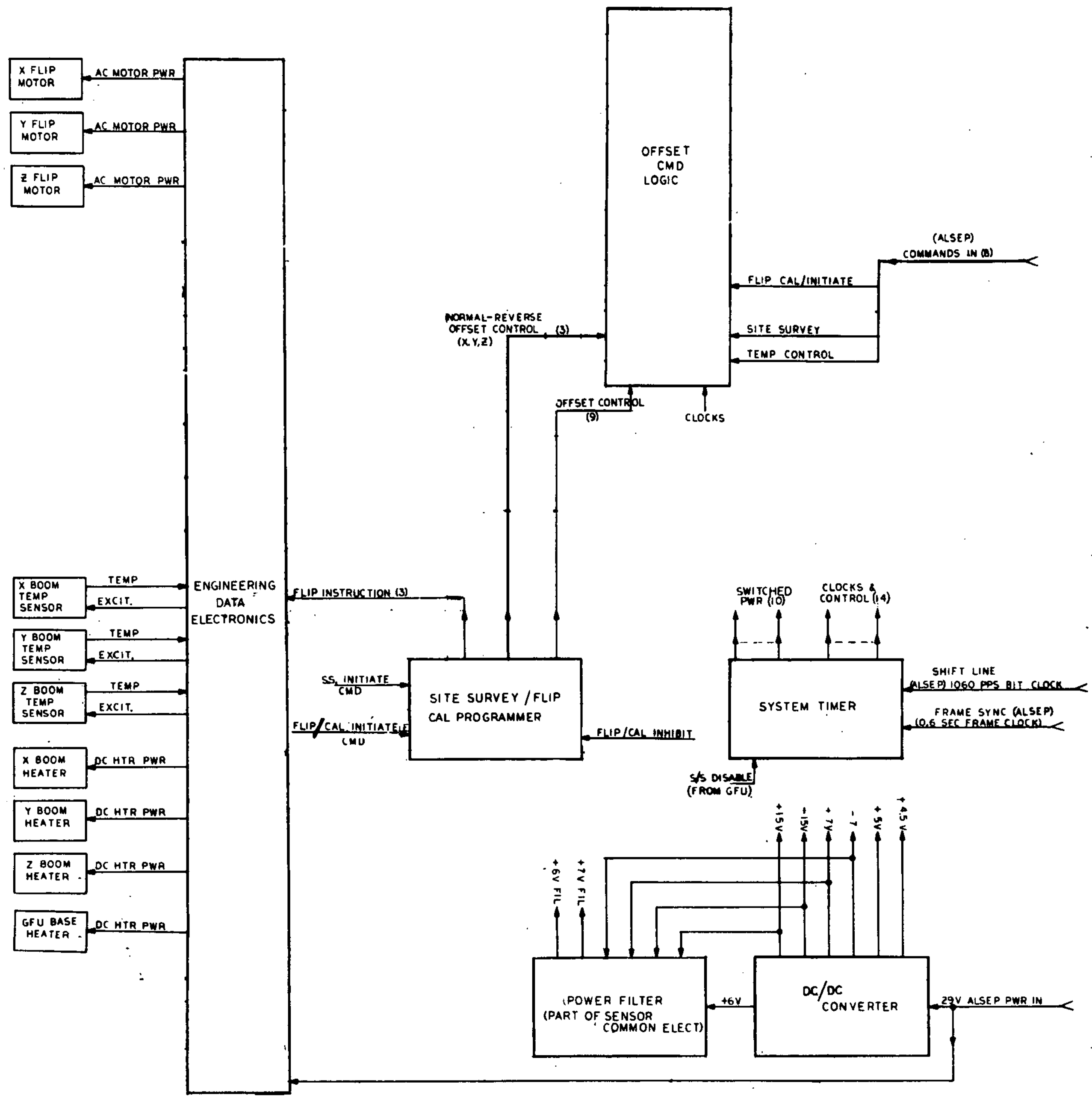
GRAVITY LEVEL ELECTRONICS



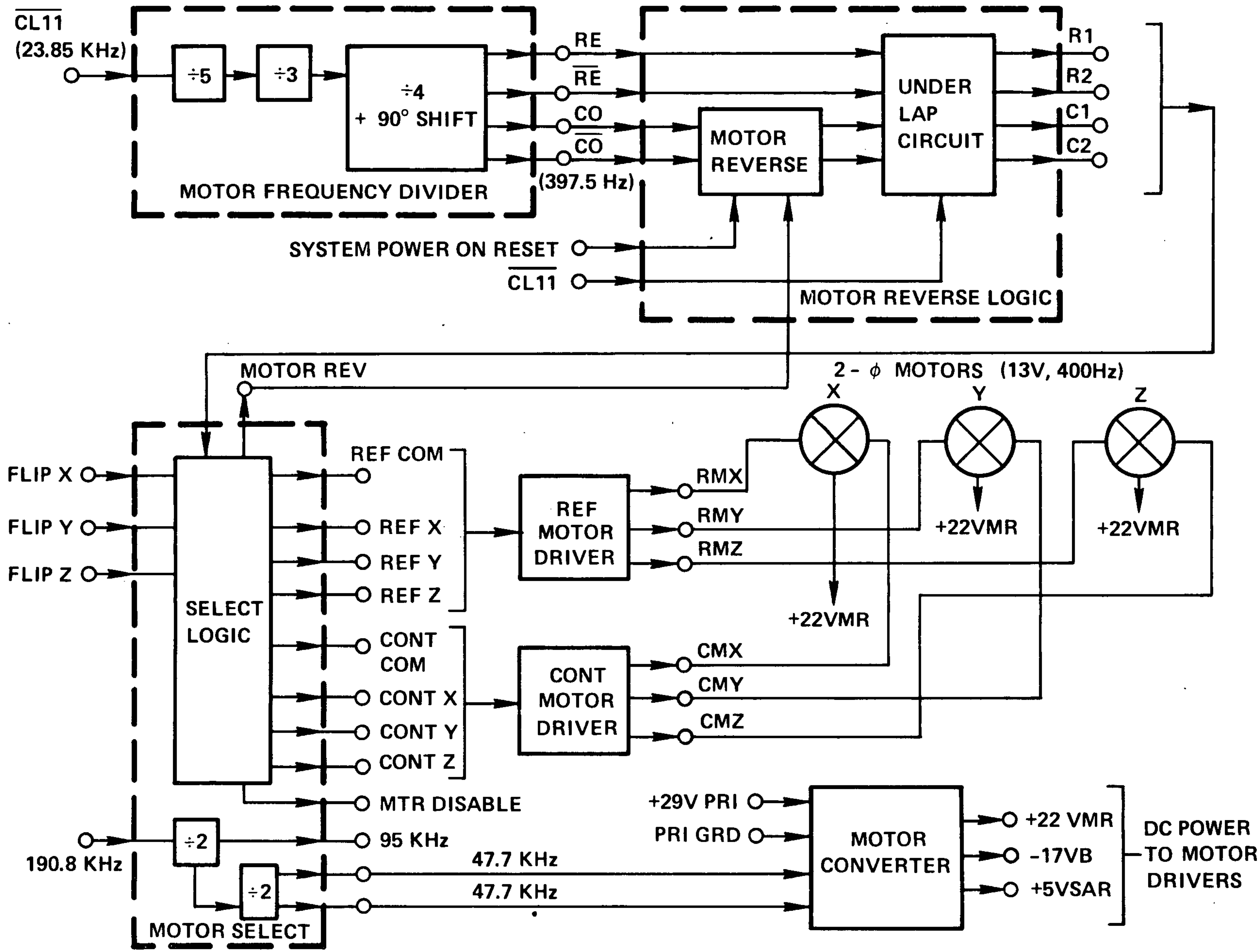
NOTES:

1. 2-AXIS GRAVITY LEVEL SENSOR
2. SENSOR IS LOCATED IN GFU
3. CONNECTIONS INTERNAL TO LEVEL SENSOR, TWISTED LEADS OUT – (4)
4. 4 INTERNAL RESISTORS NOT USED.

POWER CONTROL FUNCTIONAL DIAGRAM



MOTOR LOGIC & DRIVERS – BLOCK DIAGRAM



MECHANICAL DESIGN

C.2

REQUIREMENTS (MECHANICAL)

- WEIGHT: 19 LBS MAX.
- SIZE: SEE DRAWING
- ACCURACY: $\pm 1.5\%$
- SENSOR ORIENTATION
  - ORTHAGONAL
  - SENSOR LOCATED 24 IN. (MIN.) OVER SURFACE
  - DISTANCE BETWEEN SENSORS – 50 IN. (MIN.)
  - DISTANCE FROM ELECTRONICS – 36 IN. (MIN.)
- SENSOR FLIP
  - $180^{\circ} \pm 1^{\circ}$ – SCIENTIFIC MODE
  - $90^{\circ} \pm 1^{\circ}$ – SITE SURVEY MODE
  - NO DWELL AT INTERMEDIATE POSITIONS
  - RESTRAINING TORQUE 1.0 OZ-IN. (MIN.)
- GIMBAL
  - ROTATE EACH SENSORS $90^{\circ} \pm 1^{\circ}$
  - RESTRAINING TORQUE 5.0 IN.-OZ (MIN.)
- MUST PERFORM SITE SURVEY THEN GO TO SCIENTIFIC MODE
- NON-MAGNETIC
- MUST BE DEPLOYED WITHIN 10 MIN.
- MUST BE LEVELED ON LUNAR SURFACE
- MUST BE ALIGNED TO WITHIN $\pm 3^{\circ}$ OF LUNAR ECLIPTIC

LM INTERFACE AND DEPLOYMENT
—REQUIREMENTS—

- MUST STOW WITHIN NOTED VOLUME
- FASTENERS MUST BE REACHED FROM TOP
- VOLUME MUST CONTAIN PROVISIONS FOR ALSEP INTERCONNECT CABLE
- NO HANDLE TO BE LESS THAN 22 INCHES ABOVE LUNAR SURFACE
- DEPLOYABLE BY ONE PERSON

REQUIREMENTS (ENVIRONMENTAL)

- TWO YEAR SHELF LIFE

- VIBRATION

SINUSOIDAL

	FREQ	DESIGN VALUE ACCEL 9' PEAK TO PEAK	DESIGN VALUE x 1.3 SAFETY FACTOR
ANY AXIS	10 - 50	10	13
	50 - 100	20	26
	100 - 200	15	19.5
	200 - 500	5	6.5

(NOTCHING PERMITTED AT MAXIMUM OF 6 PLACES)

RANDOM

	FREQ RANGE	P.S.D. g^2/Hz	ACCEL g·RMS
ANY AXIS	20 - 2000	.028	7.5

- SHOCK (STOWED)

  3 MAJOR LM AXIS   32 ±2 g's -200 msec 30 ms RISE & FALL

- SHOCK (DEPLOYED)

  AXIS

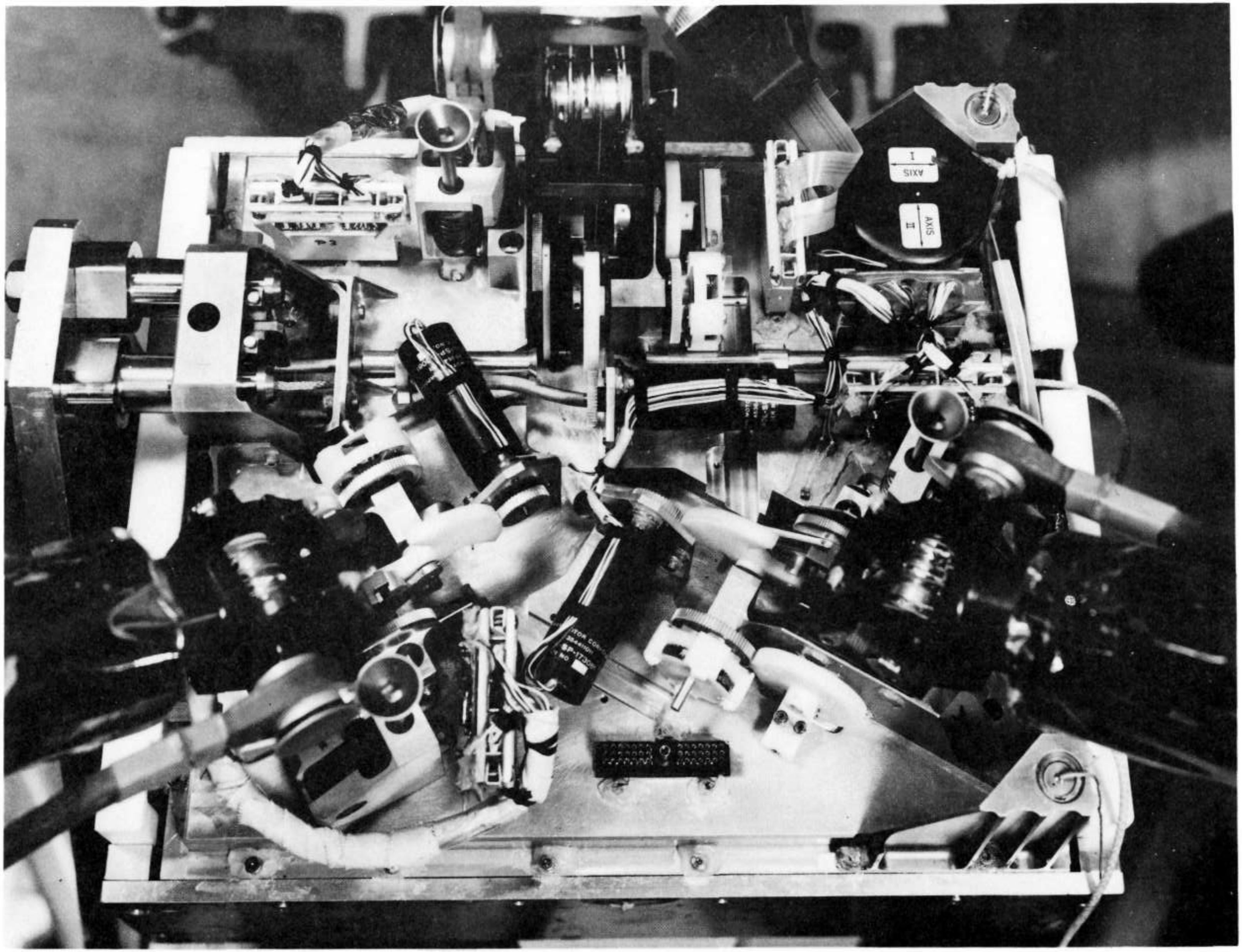
  X-X
  Y-Y   30 ±2 g's   5 ±1 ms
  Z-Z

- TEMPERATURE (INSTRUMENT)

  -50^{o}C TO $+125^{o}$C

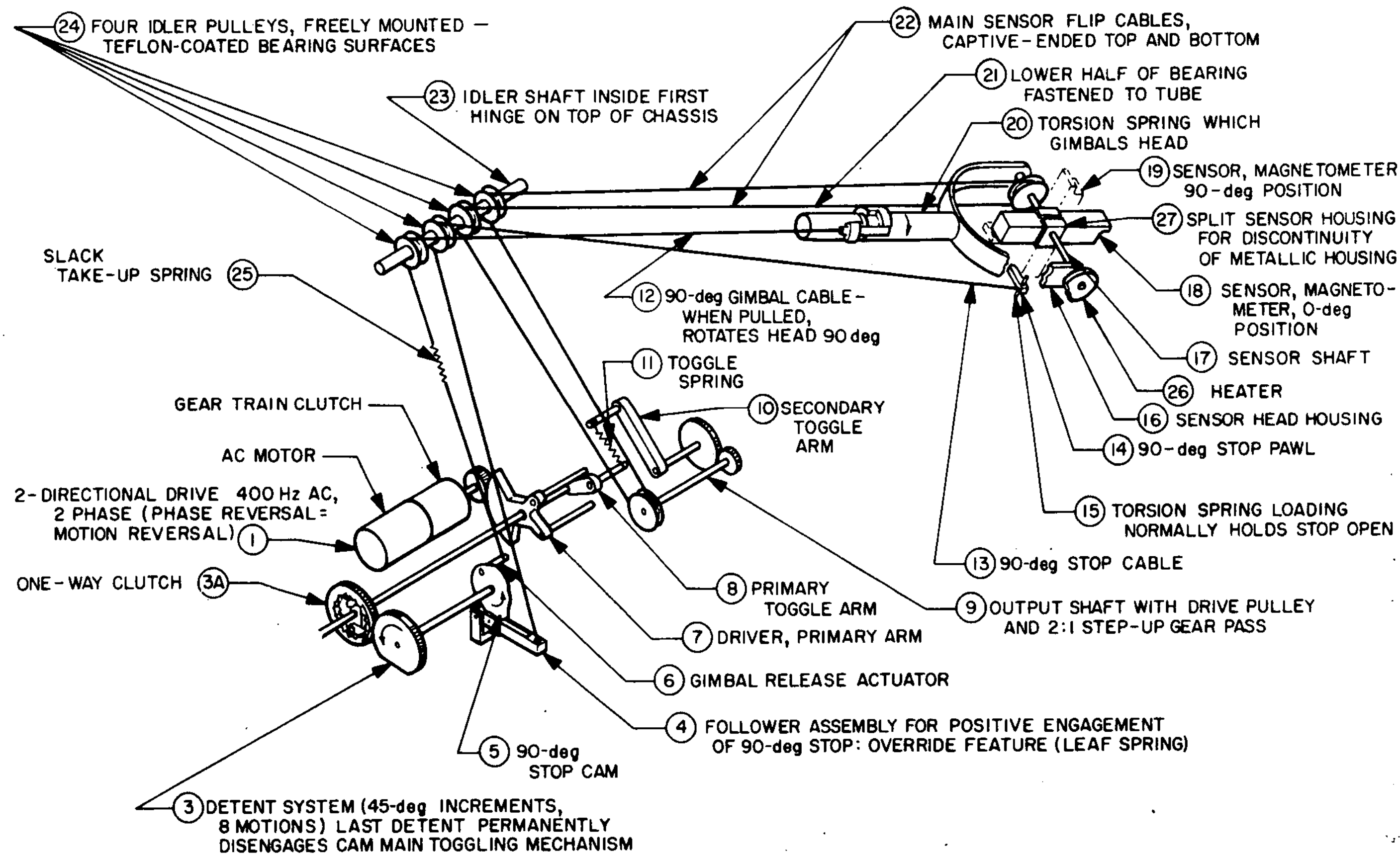
- TEMPERATURE (SENSORS)

  -30^{o}C TO $+65^{o}$C



LSM #4 Gimbal-Flip Unit Assembly

GIMBAL FLIP UNIT



L.S.M. PROCESSOR ELECTRONICS
PHYSICAL & ENVIRONMENTAL SPECIFICATIONS

I. Weight Allocation — 5.90 Lbs.
(LSM #2 weighed 6.91 lbs.)

II. Volume Allocation — 320 in^3

III. Magnetic Cleanliness (System Level), Measured at 3 feet, any axis — 2.0 gamma max.
(LSM #3 measured; X = 2.8; Y = 3.0; Z = 3.5)

IV. Vibration, Sinusoidal

Original System Spec.		Revised (Typical Z Axis)	
10 - 50 Hz	13 g	5 - 13 Hz	0.5" Double Ampl.
50 - 100 Hz	26 g	13 - 100 Hz	4.5 g.
100 - 200 Hz	19.5 g		
200 - 500 Hz	6.5 g		

Vibration, Gaussian Random

Original System Spec.	Revised (Typical Z Axis)
20 - 2000 Hz @ 0.048 g^2/Hz	20 - 2000 Hz @ .012 g^2/Hz

V. Shock (Original Spec.) — 32 ± 2 g for 200 ms

VI. Temperature

Without Dust	0^oC to + 50^oC
With Dust	-30^oC to + 65^oC
Survival	-50^oC to + 125^oC

LSM DESIGN RESTRAINTS

DESCRIPTION

1. EXTREMELY LARGE NUMBER OF ELECTRONIC PARTS WITHIN THE SPECIFIED VOLUME AND WEIGHT.
2. MAGNETIC SIGNATURE-CRITERIA FOR REDUCTION.
   a. NO MAGNETIC MATERIALS OR PARTS SHALL BE USED WHEN RELIABLE NON-MAGNETIC SUBSTITUTES CAN BE FOUND.
   b. EACH PART AND MATERIAL USED IN CONSTRUCTION SHALL BE MAGNETICALLY INSPECTED.
   c. FABRICATED PARTS MAY NOT BE CONSIDERED NON-MAGNETIC UNLESS MAGNETICALLY INSPECTED. (CHIPS, FILLERS AND MACHINE SHOP LUBRICANTS HAVE BEEN FOUND TO CAUSE MAGNETIC CONTAMINATION.)
3. INTERFACE OF ELECTRONIC SUBSYSTEM DIRECTLY WITH THE ELECTROMECHANICAL UNITS ON TOP OF THE BOX. CLOSE COUPLING OF SENSOR LINES TO THE CIRCUITS WERE NECESSARY FOR PERFORMANCE.
4. UTILIZE THE DESIGN CRITERIA AND COMMON HARDWARE FROM THE PIONEER MAGNETOMETER INSTRUMENT.

LSM DESIGN RESTRAINTS

PLAN

DEVELOP NEW PACKAGING CONCEPTS AND PROCESSES TO PRODUCE A NEW HIGH IN PACKAGING DENSITY.

DEVELOP REALISTIC APPROACHES TO POSITIVE DESIGN TECHNIQUES MINIMIZING MAGNETIC SIGNATURE – OUTLINE OF GUIDES AND DIRECTION TO LARGE NUMBER OF DESIGNER/DRAFTING FORCE. CAREFUL STUDY OF MATERIALS AND SELECTION.

INTEGRATE EXTERNAL CONNECTORS OF BOOM'S INTO SENSOR MODULE CONFIGURATION WITHIN THE UNIT.

MAGNETIC CLEANLINESS PROGRAM FOR THE LUNAR SURFACE AND PIONEER MAGNETOMETERS

THREE BASIC GUIDELINES WERE DEVELOPED AND SERVED AS THE FOUNDATIONS OF THE MAGNETIC CLEANLINESS PROGRAMS

- ELIMINATION OF ALL *HARD* (PERMANENT) MAGNETIC MATERIALS
- REDUCTION OF FIELDS DUE TO *SOFT* MAGNETIC MATERIAL
- REDUCTION OF CURRENT-INDUCED MAGNETIC FIELDS

ELECTRONIC PACKAGING DESIGN

L.S.M. PROCESSOR ELECTRONICS

PHYSICAL & ENVIRONMENTAL SPECIFICATIONS

I.	Weight Allocation (LSM #2 weighed 6.91 lbs.)	5.90 Lbs.
II.	Volume Allocation	320 in^3
III.	Magnetic Cleanliness (System Level), Measured at 3 feet, any axis (LSM #3 measured; X = 2.8; Y = 3.0; Z = 3.5)	2.0 gamma max.

IV. Vibration, Sinusoidal

Original System Spec.		Revised (Typical Z Axis)	
10 - 50 Hz	13 g	5 - 13 Hz	0.5" Double Ampl.
50 - 100 Hz	26 g	13 - 100 Hz	4.5 g
100 - 200 Hz	19.5 g		
200 - 500 Hz	6.5 g		

Vibration, Gaussian Random

Original System Spec.	Revised (Typical Z Axis)
20 - 2000 Hz @ 0.048 g^2/Hz	20 - 2000 Hz @ .012 g^2/Hz

V. Shock (Original Spec.) 32 $\pm$ 2 g for 200 ms

VI. Temperature

Without Dust	$0^\circ C$ to + $50^\circ C$
With Dust	$-30^\circ C$ to + $65^\circ C$
Survival	$-50^\circ C$ to $+125^\circ C$

L.S.M. DESIGN RESTRAINTS

Description

1. Extremely large number of electronic parts within the specified volume and weight.

2. Magnetic signature-criteria for reduction.

    a. No magnetic materials or parts shall be used when reliable non-magnetic substitutes can be found.

    b. Each part and material used in construction shall be magnetically inspected.

    c. Fabricated parts may not be considered non-magnetic unless magnetically inspected. (Chips, fillers and machine shop lubricants have been found to cause magnetic contamination.)

3. Interface of electronic subsystem directly with the electromechanical units on top of the box. Close coupling of sensor lines to the circuits were necessary for performance.

4. Utilize the design criteria and common hardware from the Pioneer Magnetometer Instrument.

Plan

Develop new packaging concepts and processes to produce a new high in packaging density.

Develop realistic approaches to positive design techniques minimizing magnetic signature - outline of guides and direction to large number of designer/drafting force. Careful study of materials and selection.

Integrate external connectors of Boom's into sensor module configuration within the unit.

Complexity

1. To perform the electrical functions a total of approximately 800 integrated circuits and 2340 discrete parts, (transistors, resistors, etc.) were used; a memory unit measuring 4.8 x 6.4 x 1.2 was also included.

2. These were packaged in 78 I.C. substrates, 38 cordwood modules and six connector modules.

3. The substrates and cordwood modules then formed 15 subsystems which were encapsulated into 20 modules plus six connector modules.

4. To connect all those parts together to form a functioning system requires over 60,000 interconnects!

5. A total of over 750 drawings are required to assemble and control the electronic package.

MAGNETIC CLEANLINESS PROGRAM FOR THE LUNAR SURFACE AND PIONEER MAGNETOMETERS

Three basic guidelines were developed and served as the foundations of the magnetic cleanliness programs:

1. Eliminate of all "hard" (permanent) magnetic materials. Any permanent magnet is constrained by the 2 gamma at 3 feet specification and adds directly to the instrument magnetic field.

2. Reduction of fields due to "soft" magnetic material. The utilization of "soft" magnetic materials was not permitted except for Kovar or Nickel leads and cases, and magnetic circuits. "Soft" magnetic materials as defined herein are those materials which may be depermed to zero, but which acquire and retain a "magnetization" when exposed to a magnetic field. It is this soft material which is most detrimental to instrument performance, since, aside from the specification, the magnetic field read by the instrument due to this source is a pure uncertainty in the data. It is this area that received the primary attention of the magnetics control program.

3. Reduction of current-induced magnetic fields. Layouts of a given circuit, even though designed with non-magnetic parts and materials, may still give magnetic problems if proper procedures are not followed. The magnetic field produced by a small current loop in an iron free region is proportional to the product of:

   a. The average area enclosed by the loop,

   b. The number of turns, and

   c. The current.

   It is in this area, that the layout and orientation of the parts and the functional circuitry were important.

STUDIES & TESTS

Using the magnetic cleanliness guidelines, extensive studies and tests were made with the following results:

- Close proximity packaging was mandatory for the reduction of instrument magnetic signature.

- <u>Passive Elements</u>

  Resistors and capacitors are without exception specified to be nonmagnetic. In some isolated instances, resistors with Kovar end caps were accepted. For the most part, Angstrohm and Allen-Bradley resistors with oxygen-free copper leads were chosen.

  (Magnetic circuits of both powdered iron and tape-wound cores were used. Recognizing that the iron is prone to spreading stray field, care was taken to achieve stray field cancellation.)

- The use of glass sealed parts dictated the use of magnetic materials (i.e., Kovar, dument or diodes, transistors, and I.C. circuits).

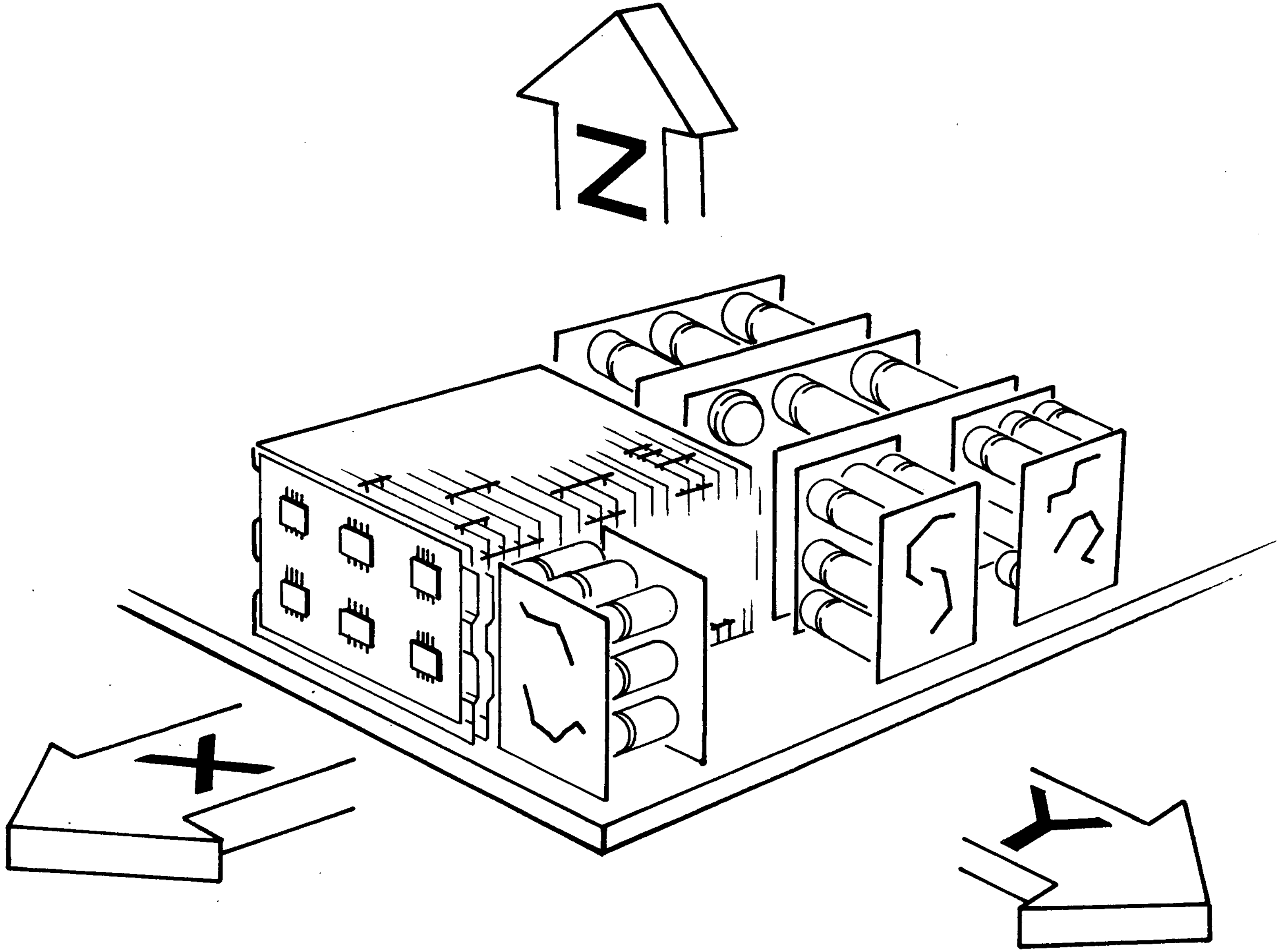
- The minimum feasible lead length must be used. (0.060 inches was determined to be the minimum lead length required for welding.)

- Welding was chosen for close part proximity connection, weight and reliability.

- Orientation of parts was critical for the reduction of dipoles and current loops.

- The large number of integrated circuits dictated the I.C. module design as the controlling restraint to the magnetic cleanliness requirement.

- The optimum packaging technique is to place the I.C.'s in a vertical stack with minimum separation.


Z
X
Y

Integrated Network Module System

The integrated networks are parallel-gap welded to copper-clad glass epoxy boards. The etched patterns on the board are designed on the bases of:

- Minimum Conductor Routing
- Minimum Interconnections
- Repeatability in the printed wiring board configuration.

Grouping of the integrated networks is accomplished through overall circuit analysis of the system.

The I.C. board configuration became of extreme importance early in the instrument design, to meet the following requirements.

- Minimize integrated network lead length to reduce magnetic material in instrument.

- Minimize board material thickness to reduce weight and volume.

- Control board height because of instrument width.

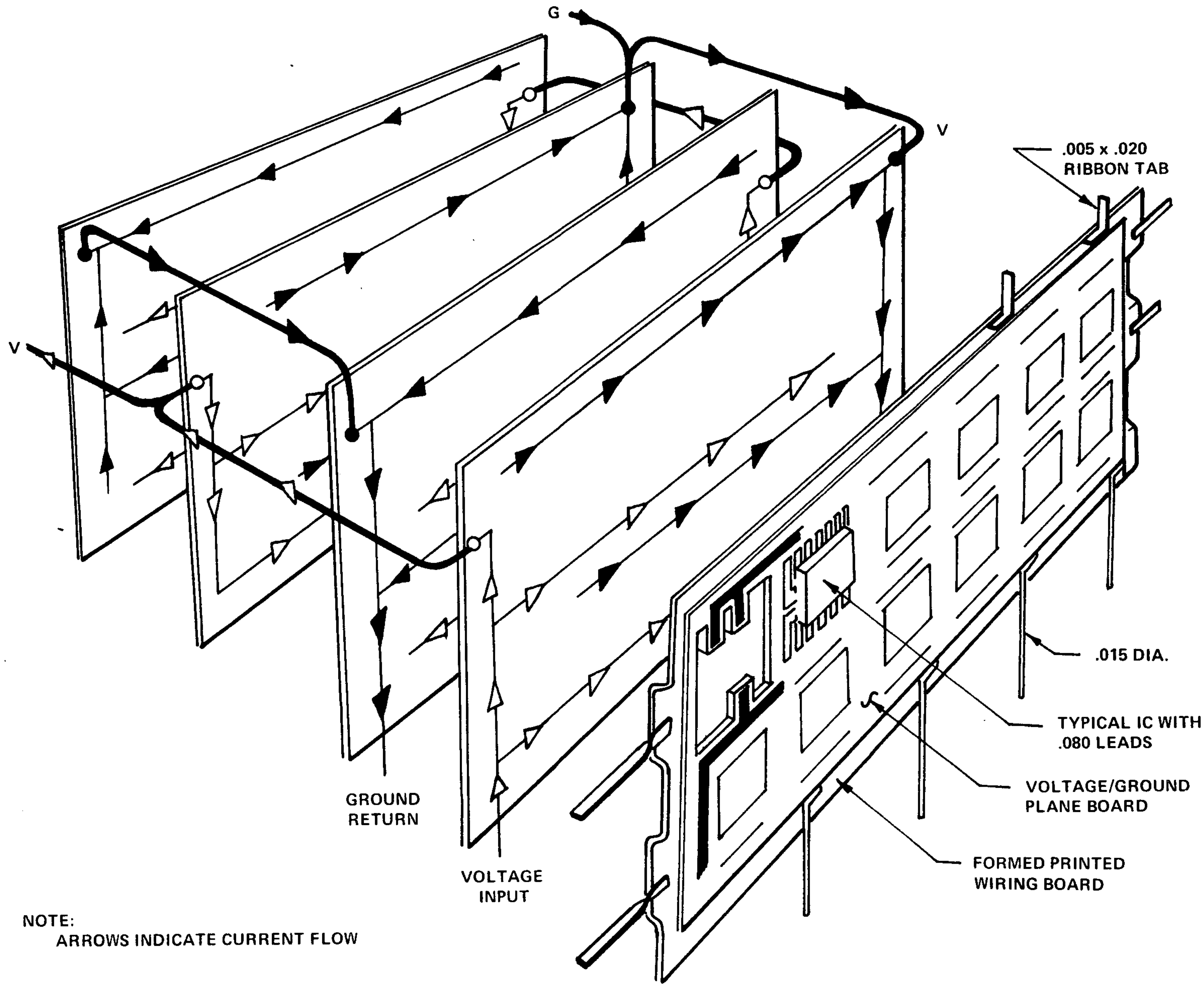
- Control voltage and ground arrangement to aid in cancelling the induced magnetic field effect.

Normally, integrated network leads are preformed for installation onto a board using a minimum of .120 inch lead length (.060 for bend area, and .060 for attachment). However, with approximately 11,956 leads involved, it was advantageous to eliminate the excess lead material in the bend area. After considering tolerances, it was possible to reduce the lead length to .080, thus saving 1.00 inch per integrated network, or <u>71 feet of magnetic material</u> in the instrument.

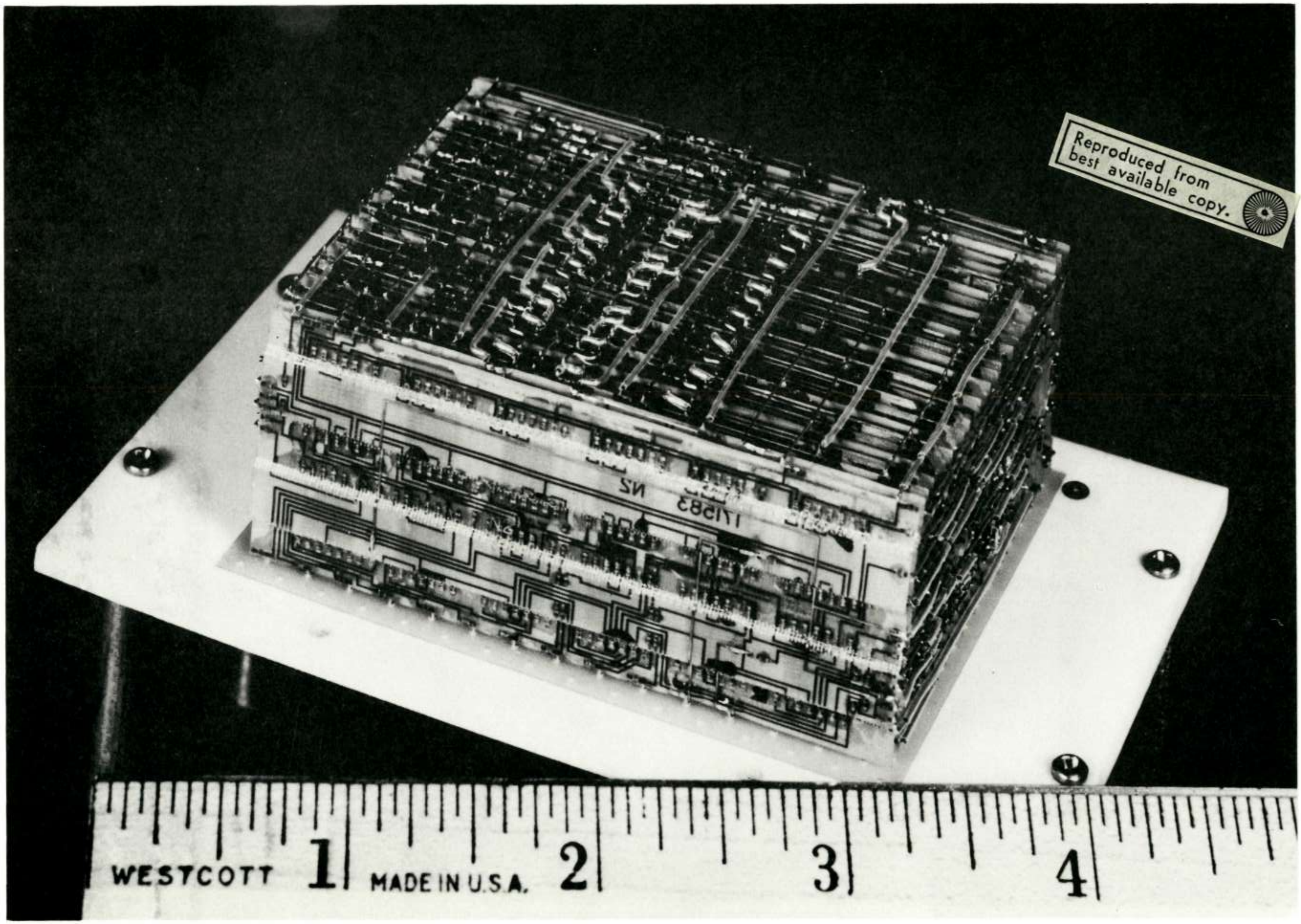
$$
\begin{array}{lr}
.120 - .080 = (.040) \times (10 \text{ leads})(854) & 341.60 \text{ inches} \\
.230 - .080 = (.150) \times (\ 4 \text{ leads})(854) & \underline{512.40} \text{ inches} \\
 & 854.00 \text{ inches}
\end{array}
$$

180 alloy ribbon extensions were added on to leads 1, 7, 8 and 14 to bring them in line with the remaining pattern.

GROUND & VOLTAGE LINE LAYOUT



NOTE:
ARROWS INDICATE CURRENT FLOW



LSM Arithmetic Module

Formed Printed Board

With the excess magnetic material removed and a smaller mounting pattern available, the remaining problem was attachment. This was accomplished by forming the printed wiring board material. The etched .004-inch thick copper-clad glass epoxy board is permanently formed by temporarily exposing the material to a temperature above the initial cure temperature and then applying pressure. Figure ____ shows the formed board.

This technique produced two trough areas along the board for integrated network installation, strengthened the board, allowed use of the smaller I.C. mounting pattern, and minimized overall board assembly thickness.

Circuit requirements demanded the use of both the front and rear sides of the printed wiring board for conductor routing. The transition from one side of the board to the other is accomplished by using 180 alloy ribbon feed-throughs, .005 x .020 inches in cross-section. The feed through is parallel gap welded to a conductor pad and passes through an access hole to a conductor pad on the opposite side of the board. Jumpering on a given side of a board is accomplished by insulating the conductor area and strapping across with the .005 x .020 180 alloy ribbon. Each board has .005 x .020 180 alloy ribbon leads parallel gap welded onto etched conductor pads provided near the edges of the printed wiring board. The bottom, or base edge, of the board has pads on a tenth inch grid and is used for thos signals that must pass to other functions outside the module. The other three edges have the pads positioned on a .050 inch grid and are used for interconnects between printed wiring boards within the same module.

A separate substrate was used to control the power and ground conductor arrangement throughout the group of integrated network boards. Alternating the ground and power conductor pattern throughout the board grouping helped in cancelling the inducted magnetic field effect.

The required voltage and ground plane conductors are etched on a standardized .004 thick copper-clad glass epoxy board. A standard cutout was developed for the network area and punched into the substrates at the respective 6 and 12 positions.

The voltage and ground plane substrate is then bonded to the top surface of the formed board using a double back thermosetting tape placed on the substrate prior to punching.

The integrated networks are parallel-gap welded onto the board and power and ground pads to complete the board assembly. The six-position board measured .080 x 1.150 x 1.460 while the 12-position board was .080 x 1.150 x 3.010.

The assembled boards are positioned vertically onto a .010 thick epoxy board base header. The boards are located on .080-inch increments. The standard grid normally used for I.C. modules is .100-inch centers; however, the extremely thin formed board made it possible to reduce the space required by 20%.

Interconnections between boards are accomplished with .010 x .015 180 alloy ribbon resistance welded to the ribbons positioned around the board (see Figures _____ and _____). The interface to the base or external connections is via .015 diameter 180 alloy welded to the ribbons bent at right angles along the bottom edge of the board.

The completed integrated circuit module is then encapsulated with a lightweight foam embedment CPR 17-2A, CO2 blown polyurethane foam. Electrical testing of the integrated network board is accomplished at the individual board using suitable test fixture adapters, and at the module level prior to the embedment process.

Cordwood Module System

This concept packages a functional group of discrete electrical components by stacking them in "cordwood" fashion between mylar welding planes or substrates. These substrates are photographically reproduced identification layers which locate parts placement, welded ribbon routing, and outgoing pin locations. This module is oriented either vertically or horizontally with respect to the mounting or thermal surface of the multilayer panel.

Actual orientation is based on overall parts grouping and conductor routing as an aid in reducing the magnetic signature of the instrument. Component leads with magnetic material are clipped to .080 lengths and 180 alloy .015 inches in diameter is resistance welded to the remaining portion.

Modules requiring shielding are enclosed in .005 thick gold plated copper covers. The covers are terminated either to a signal ground lead provided at the top of the module, or fully enclosed by soldering to a .005 thick gold plated copper sheet at the base of the module. After pre-pot testing is completed, the modules are encapsulated in a lightweight foam embedment. The shield cover is used as the module mold during the embedment process. Accurately machined molds are used to establish the outline dimensions during the embedment process for the remaining modules.

T-Frame Module System

Circuitry containing high heat dissipating components are packaged into the "T" frame module configuration. These are the DC/DC converter, the motor converter, and the motor driver. Each module consists of a gold plated aluminum frame onto which are cemented the electronic components. The metal frame also contains the mechanical components required for mounting the module and acquiring electrical continuity to the interconnect board and thermal plane. The electronic parts are interconnected by use of miniature resistance welding techniques. Interconnection ribbons of .010 x .015 180 alloy are welded from point to point. A .005 thick gold-plated copper cover is placed over the assembly and sealed to the mounting flange. The module is then encapsulated with a lightweight foam embedment.

Processor Electronics Subsystem Components

The LSM Processor Electronics Subsystem is housed within the electronics Gimbal Flip Unit (EGFU). Three separate electronic assemblies plus the chassis and cover make up the subsystem. The electronic assemblies are as follows:

1. A-1 interconnect or motherboard which supports and interconnects all analog function modules.
2. A-2 interconnect or motherboard which supports and interconnects all digital function modules.
3. A-3 interconnect harness which interconnects the A-1 and A-2 boards.

The modules on the A-1 board include the following:

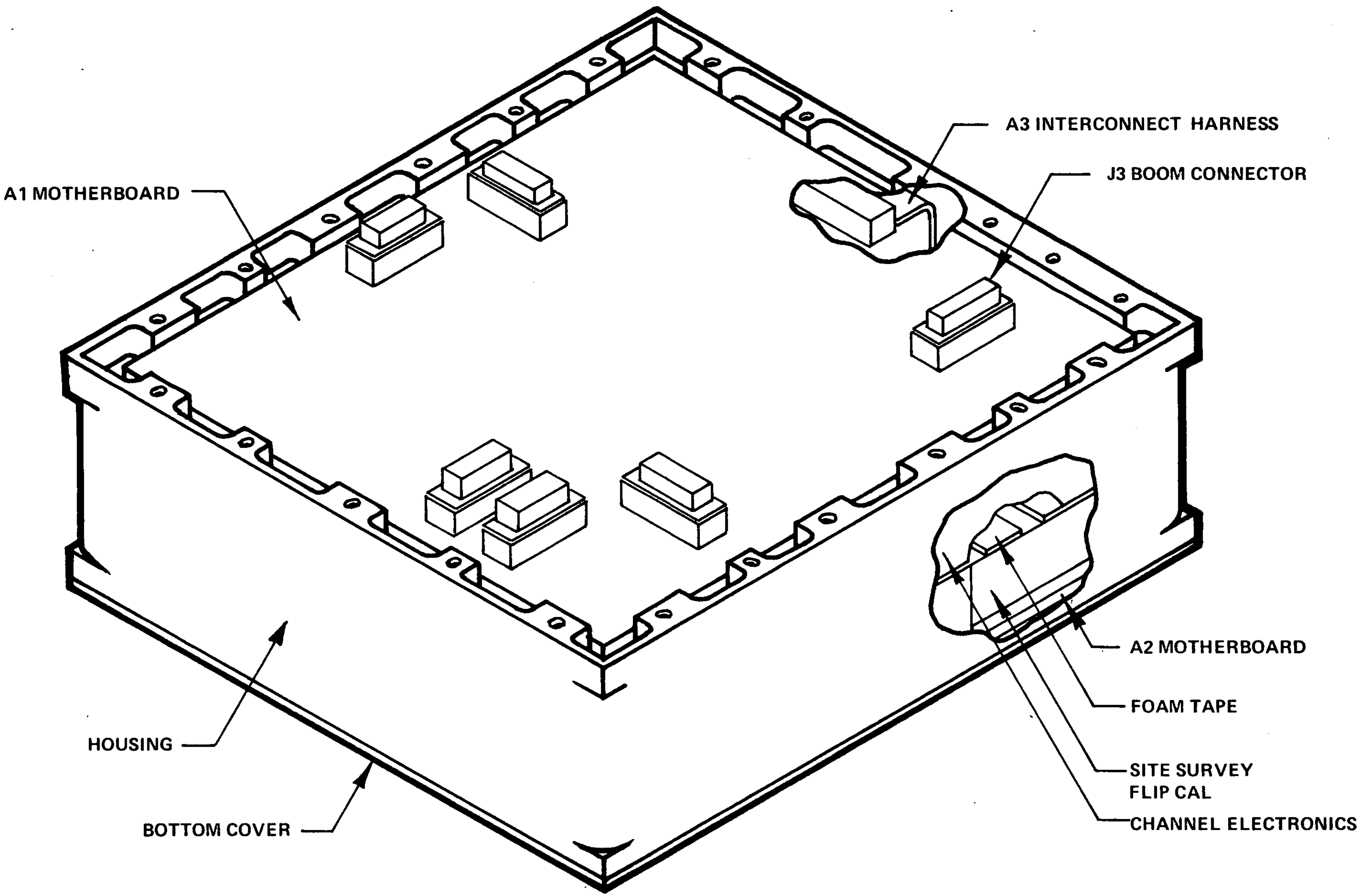
1. Multiplexer and A/D Converter Module
2. Engineering Data Electronics Module
3. Magnetic Sensor Electronics Module
4. Sensor Driver Modules
5. Calibrate/Offset Bias Generator Module
6. Electrical Interface Connector Modules

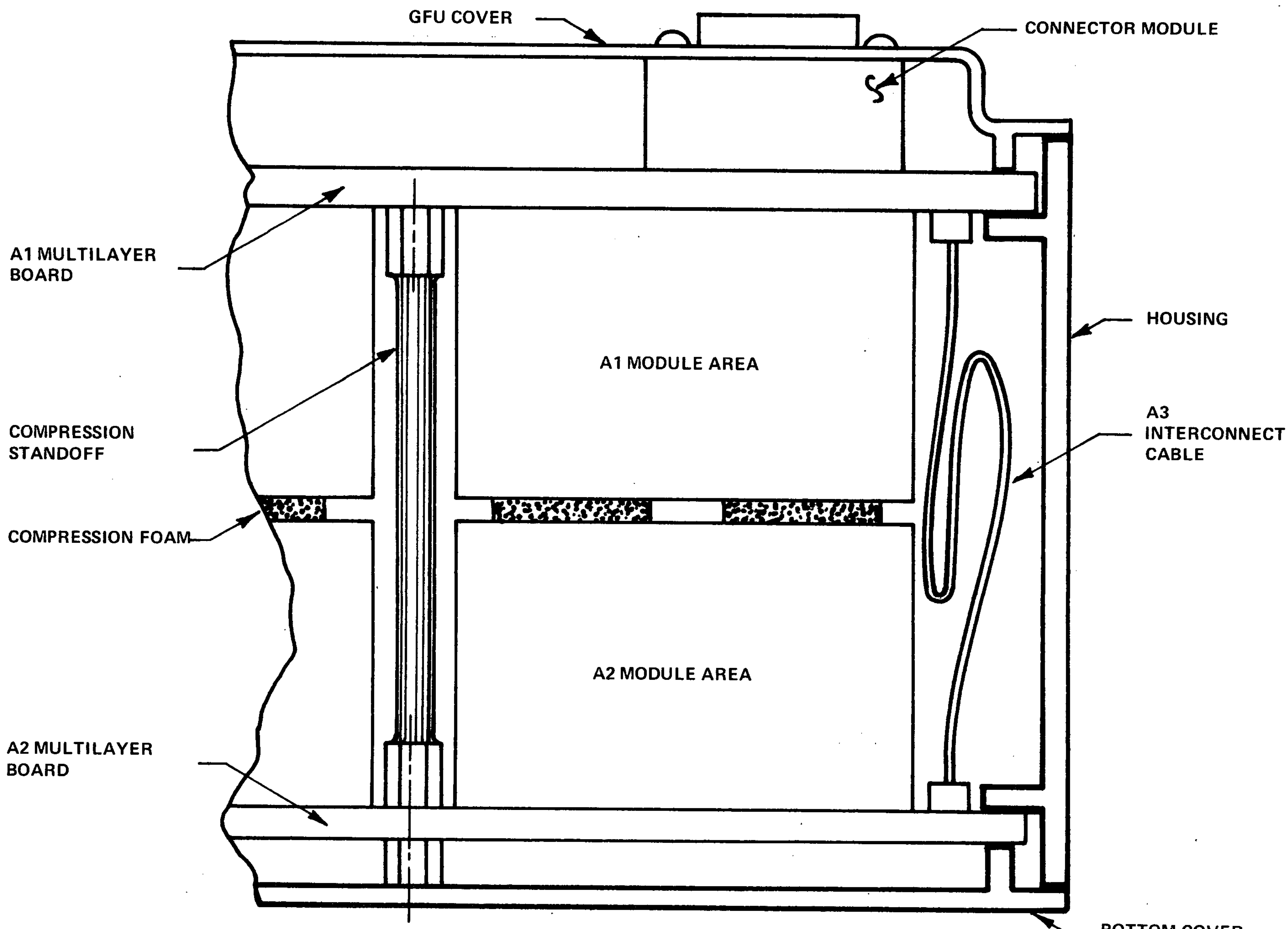
The digital modules on the A-2 board include:

1. Arithmetic Module
2. Scientific Sequencer Module
3. Engineering Sequencer Module
4. Site Survey/Flip Calibrate Sequencer Module
5. Output Data Buffer Module
6. System Timer Module
7. Power (DC-DC) Converter Module
8. Memory
9. Offset Command Logic Module

The two interconnect boards are 10-layer epoxy laminates with copper circuit traces, a voltage ground, and a heat sink layer. Tubelets penetrate the board where connections are to be made and are tab-welded to the proper trace.

The two boards are themselves interconnected by means of the A-3 interconnect. This is a group of several independent multiple conductor ribbon cables with flat copper conductors imbedded in mylar. Each cable connects between terminal strips which are part of the A-1 and A-2 boards.


A3 INTERCONNECT HARNESS
J3 BOOM CONNECTOR
A1 MOTHERBOARD
A2 MOTHERBOARD
FOAM TAPE
SITE SURVEY
FLIP CAL
CHANNEL ELECTRONICS
HOUSING
BOTTOM COVER


GFU COVER
CONNECTOR MODULE
A1 MULTILAYER BOARD
HOUSING
A1 MODULE AREA
A3 INTERCONNECT CABLE
COMPRESSION STANDOFF
COMPRESSION FOAM
A2 MODULE AREA
A2 MULTILAYER BOARD
BOTTOM COVER

The subsystems are installed from opposite sides of the housing, positioned on internal rails, and loaded in compression against one another. The loading is accomplished using:

- o Threaded fasteners in the rail areas,
- o Standoff posts through the center section,
- o With compression fingers provided around the internal periphery of the two external covers, and
- o A controlled foam interface between the subsystems.

This arrangement was chosen for the following reasons:

1. The unusual envelope configuration was needed to mate with the G.F.U. interface.

2. The 2.57 inch dimension between rails is twice the height needed to package high density welded modules, and with the extremely large number of components required, back-to-back installation was feasible.

3. One of the main design goals in minimizing the magnetic signature of the instrument was to keep component circuits close together to aid in cancelling the induced magnetic field effect.

4. Weight was of primary importance in choosing this arrangement. Less structure was required to stiffen the unit, and therefore less mass involved.

5. The mounting rails, in addition to being structural members, serve as a thermal surface for the two modular subsystems.

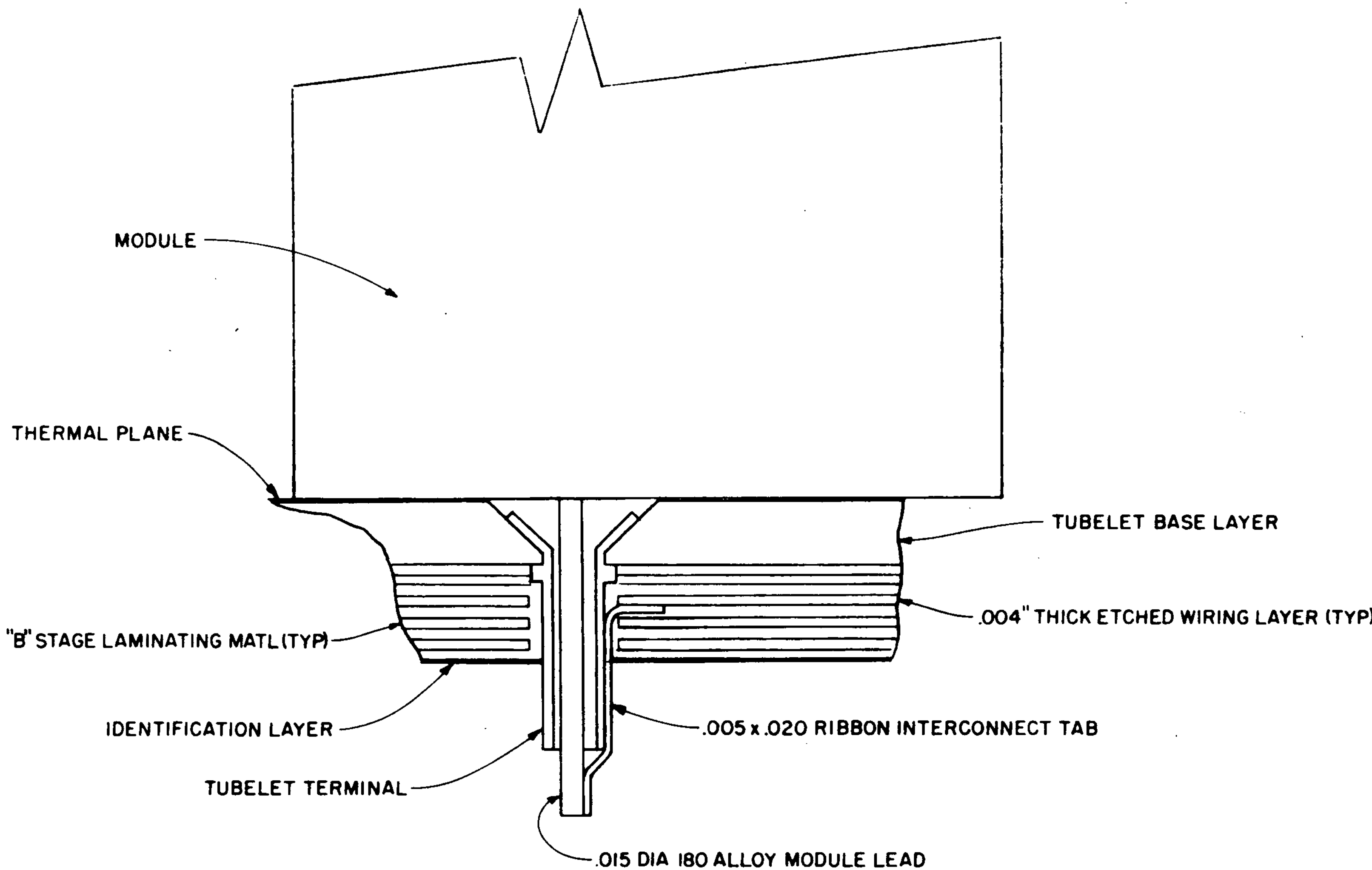
Interconnection Panel

The interconnection panel serves as an interconnection system, a structural member, and a thermal conduction plane for the module groupings.

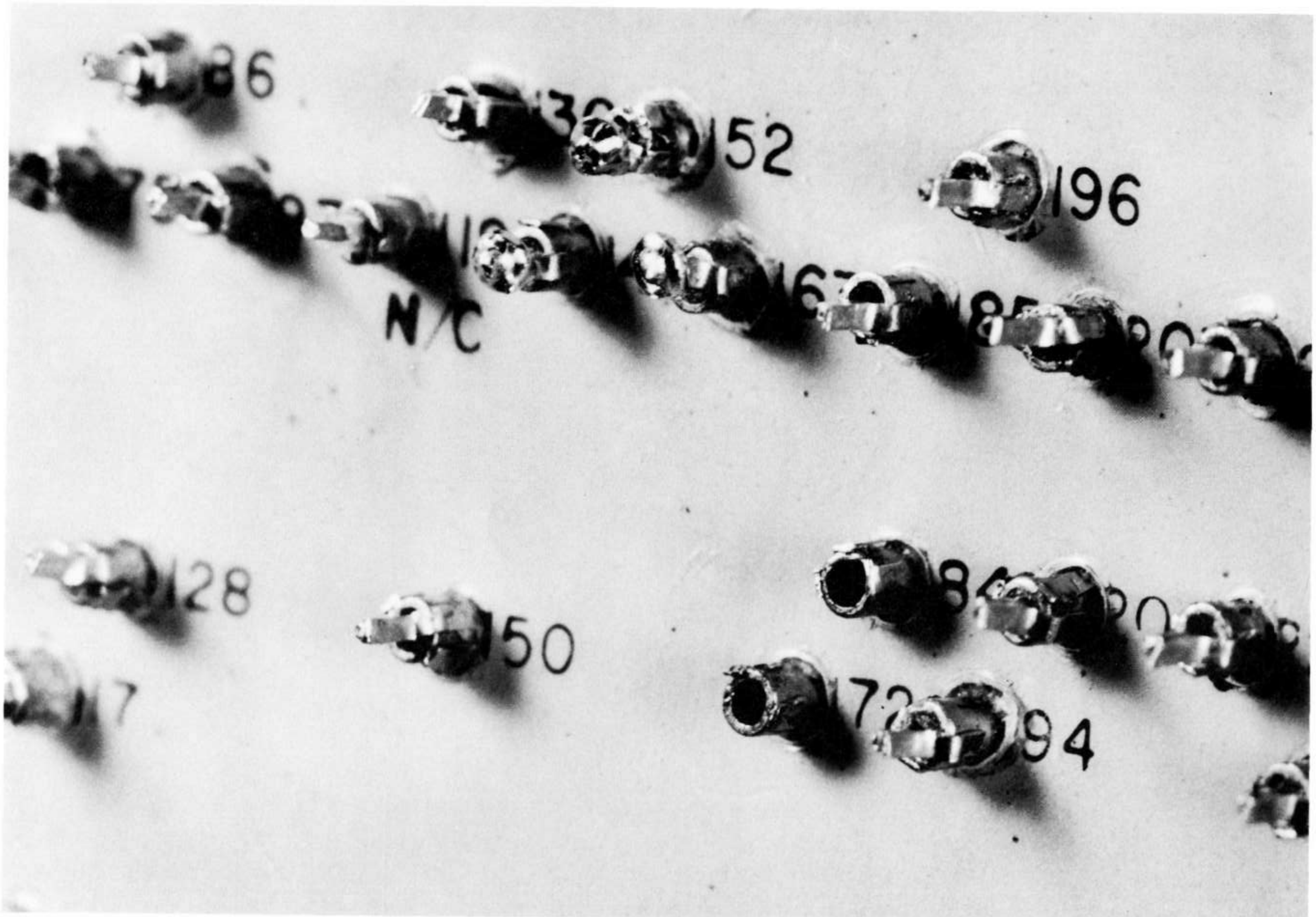
The welded multilayer interconnection panel consists of a series of stacked etched .004 thick copper clad printed wiring layers that are electrically connected using miniature brass tubelet terminals. A .005 x .020 180 alloy ribbon tab is welded to printed wiring pads bent at a right angle, and welded to the adjacent tubelet after lamination.

The first or base layer is a .062 inch glass epoxy printed wiring board into which the tubelet terminals are swaged. The front side contains circuitry for required voltage and ground interconnect. The rear side contains full cladding of .0028-inch thick copper, gold plated, with clearances at the tubelet positions. This surface serves as a direct thermal path for the individual modules to the housing rails. The remaining layers are stacked onto the base layer, using pre-drilled tubelet clearance holes as an indexing guide. For lamination, .005 thick "B" stage glass epoxy adhesive is placed between each layer during the stacked operation.

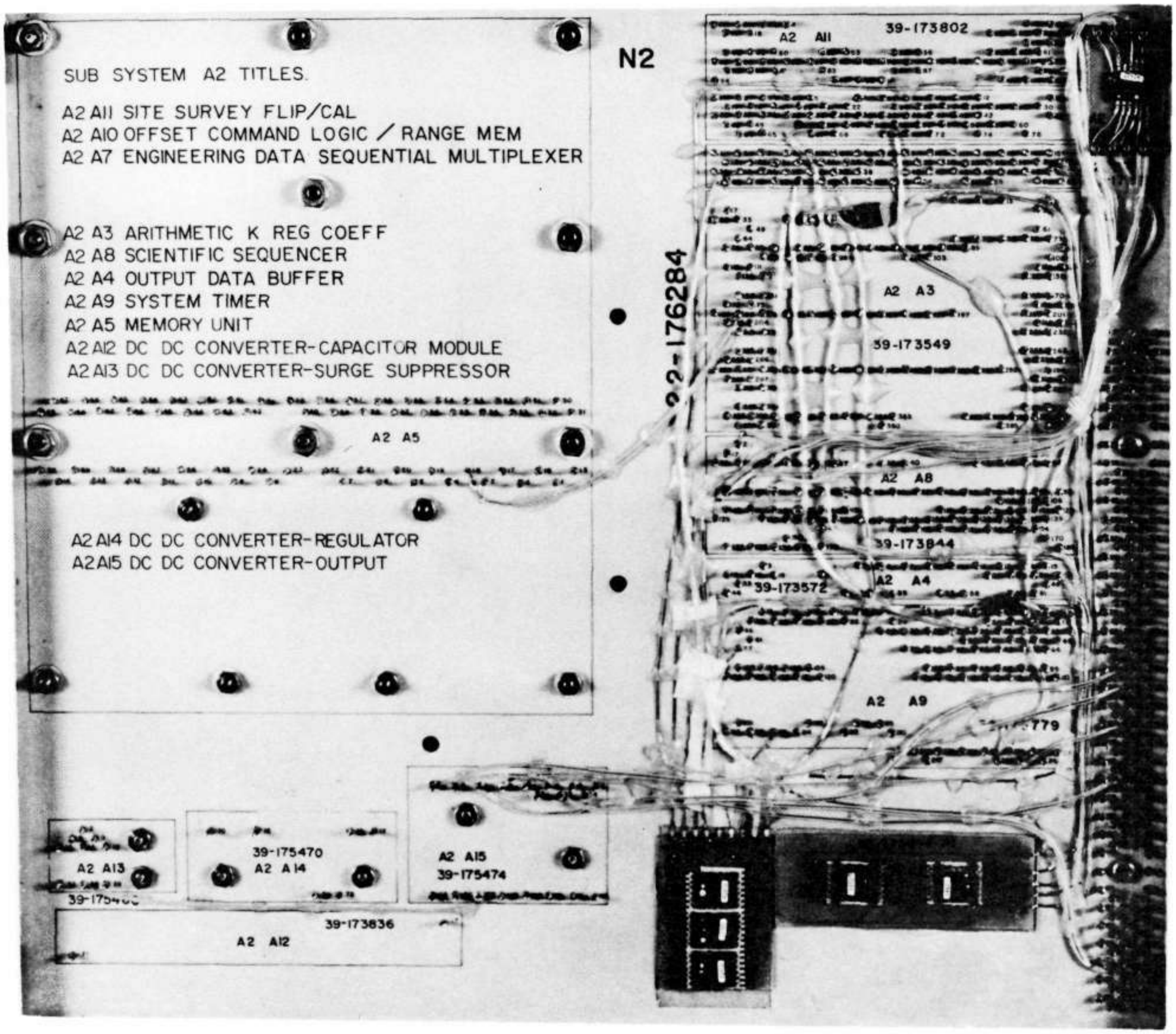
The final or top layer is the exposed surface of the panel, and serves as an identification aid. Information photographically produced on this mylar layer includes the reference outline of positioned modules located on the opposite surface of the panel, module reference designations, and module lead location with pin numbers identified. The rear surface of this mylar layer is coated with a pigmented epoxy paint. The transparency of the mylar film positive permits the Cat-L-Ink to become the background color. This produces a color contrast of black characters and reference outlines against a green surface, resulting in a satisfactory level of legibility.



Interconnection Panel Assembly



LSM Motherboard Tubelets - A



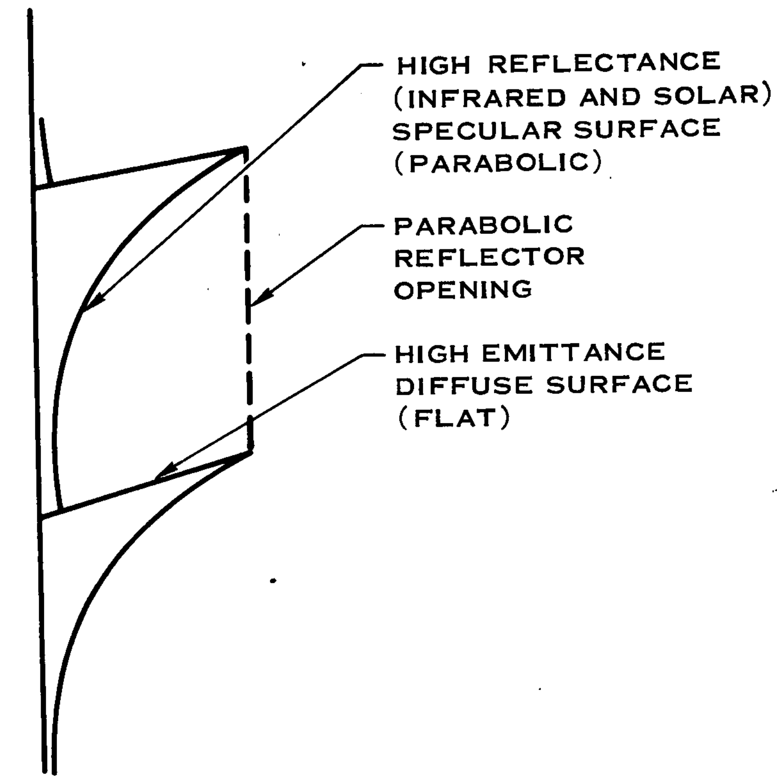
LSM #7 "B" Motherboard

THERMAL DESIGN

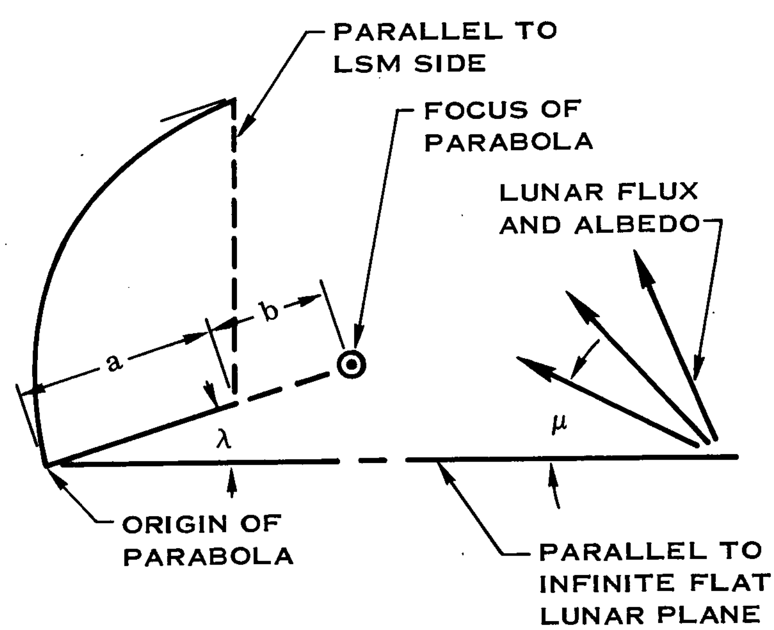
THERMAL DESIGN REQUIREMENTS AND CONSTRAINTS

- TEMPERATURE LIMITS (OPERATING)
  - $-30^{o}C$ TO $+65^{o}C$ – ELECTRONIC & SENSOR
  - $5^{o}C$ MAX. ΔT BETWEEN SENSORS
  - $-173^{o}C$ TO $130^{o}C$ LUNAR SURFACE
- ANGULAR ALIGNMENT AND PLACEMENT
  - $\pm 5^{o}$ DEPLOYMENT FROM EQUATOR
  - $\pm 3^{o}$ AZIMUTH
  - $\pm 3^{o}$ ELEVATION
  - $\pm 3^{o}$ ALIGNMENT
- DUST CONSTRAINT (MODIFIED)
  - DUST ON EXTERIOR HORIZONTAL SURFACE ONLY
  - $a_s = \epsilon = 0.9$
- POWER

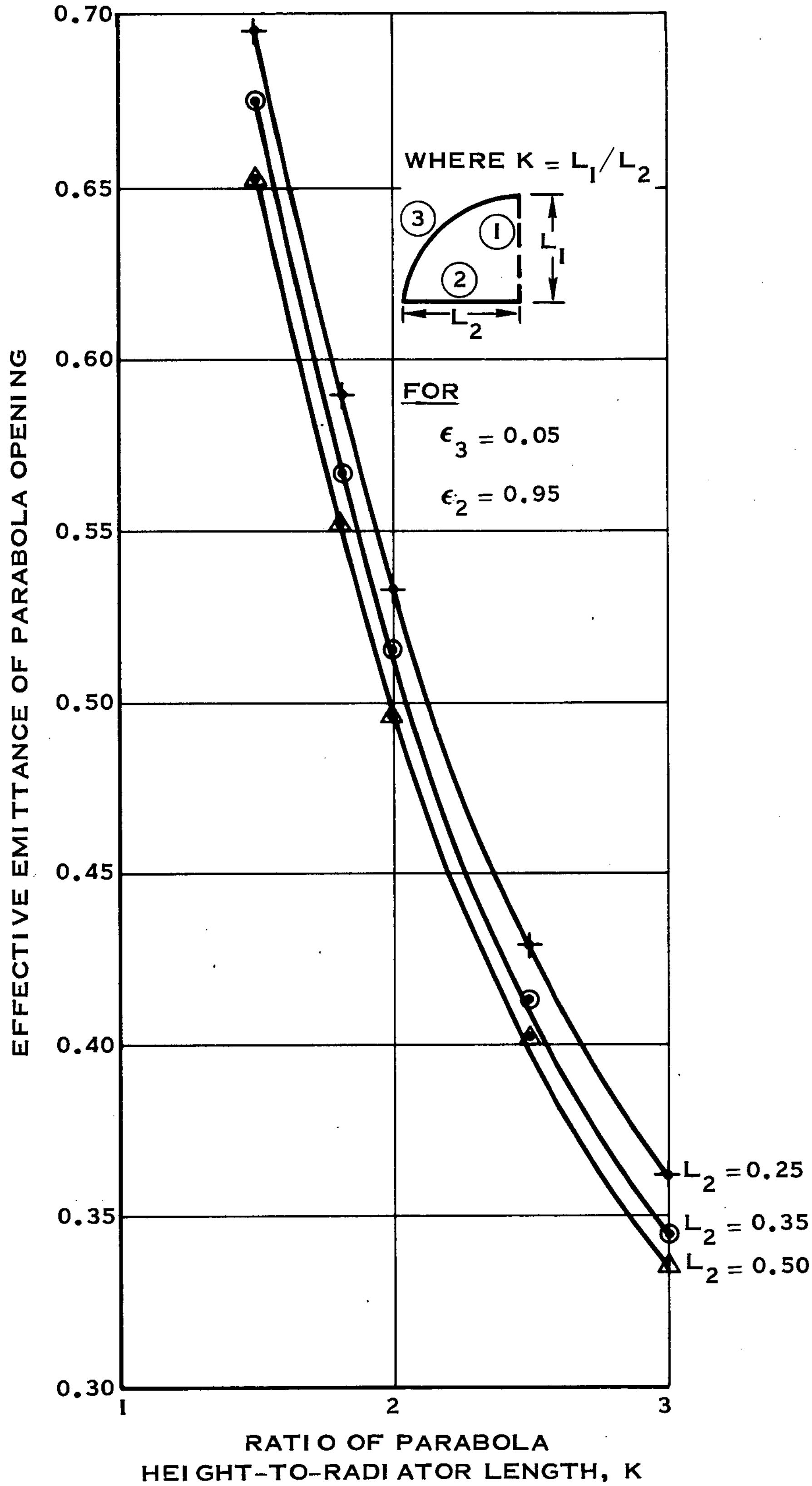
ELECTRONICS	3.5 WATT AVERAGE
GFU HEATER	2.8 WATTS MAX.
SENSOR HEATER	1.0 WATTS MAX./SENSOR

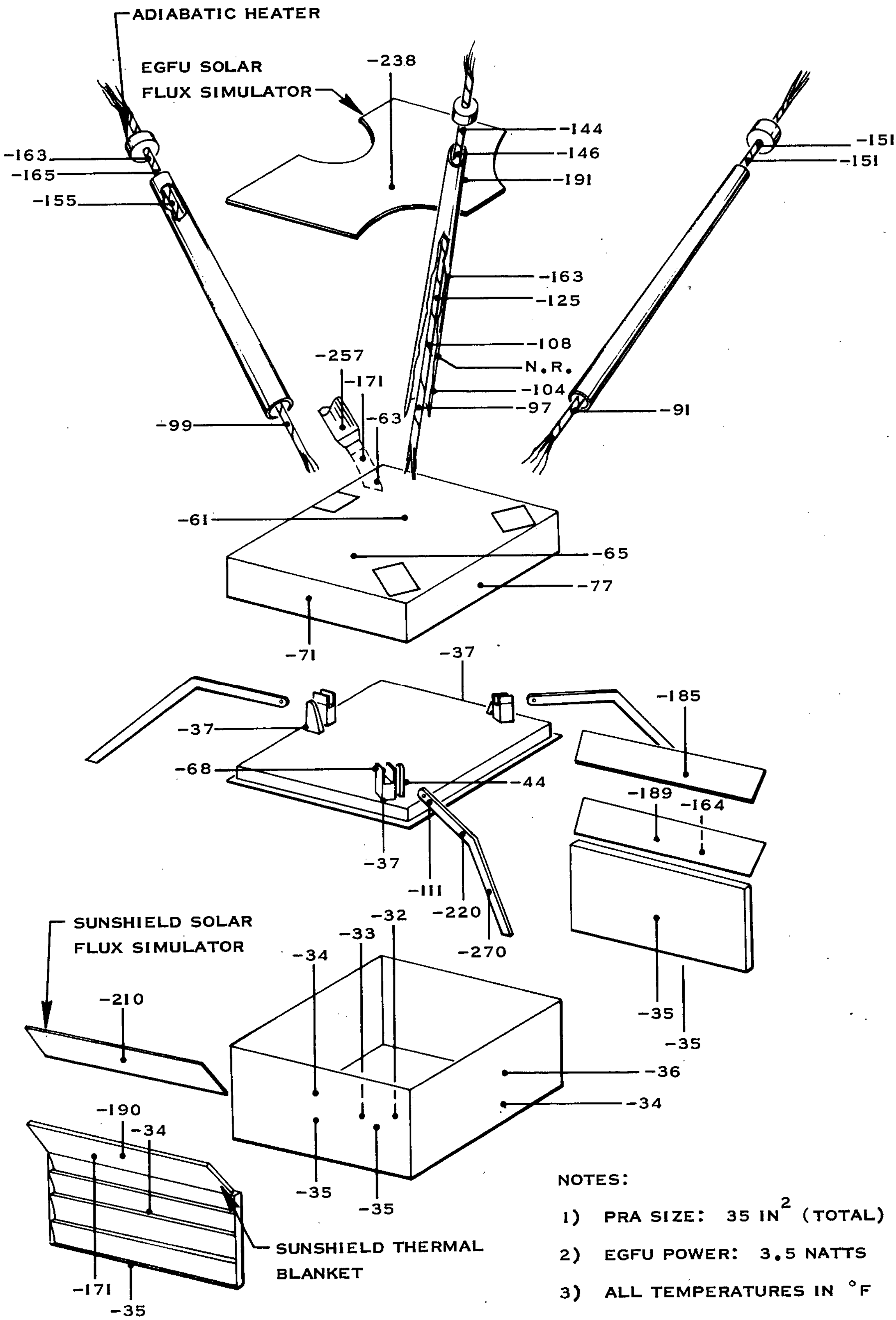


HIGH REFLECTANCE (INFRARED AND SOLAR) SPECULAR SURFACE (PARABOLIC)
PARABOLIC REFLECTOR OPENING
HIGH EMITTANCE DIFFUSE SURFACE (FLAT)



PARALLEL TO LSM SIDE
FOCUS OF PARABOLA
LUNAR FLUX AND ALBEDO
a
b
λ
μ
ORIGIN OF PARABOLA
PARALLEL TO INFINITE FLAT LUNAR PLANE


WHERE K = L1/L2
3
1
2
L1
L2
FOR
ε3 = 0.05
ε2 = 0.95
L2 = 0.25
L2 = 0.35
L2 = 0.50
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
1
2
3
EFFECTIVE EMITTANCE OF PARABOLA OPENING
RATIO OF PARABOLA
HEIGHT-TO-RADIATOR LENGTH, K

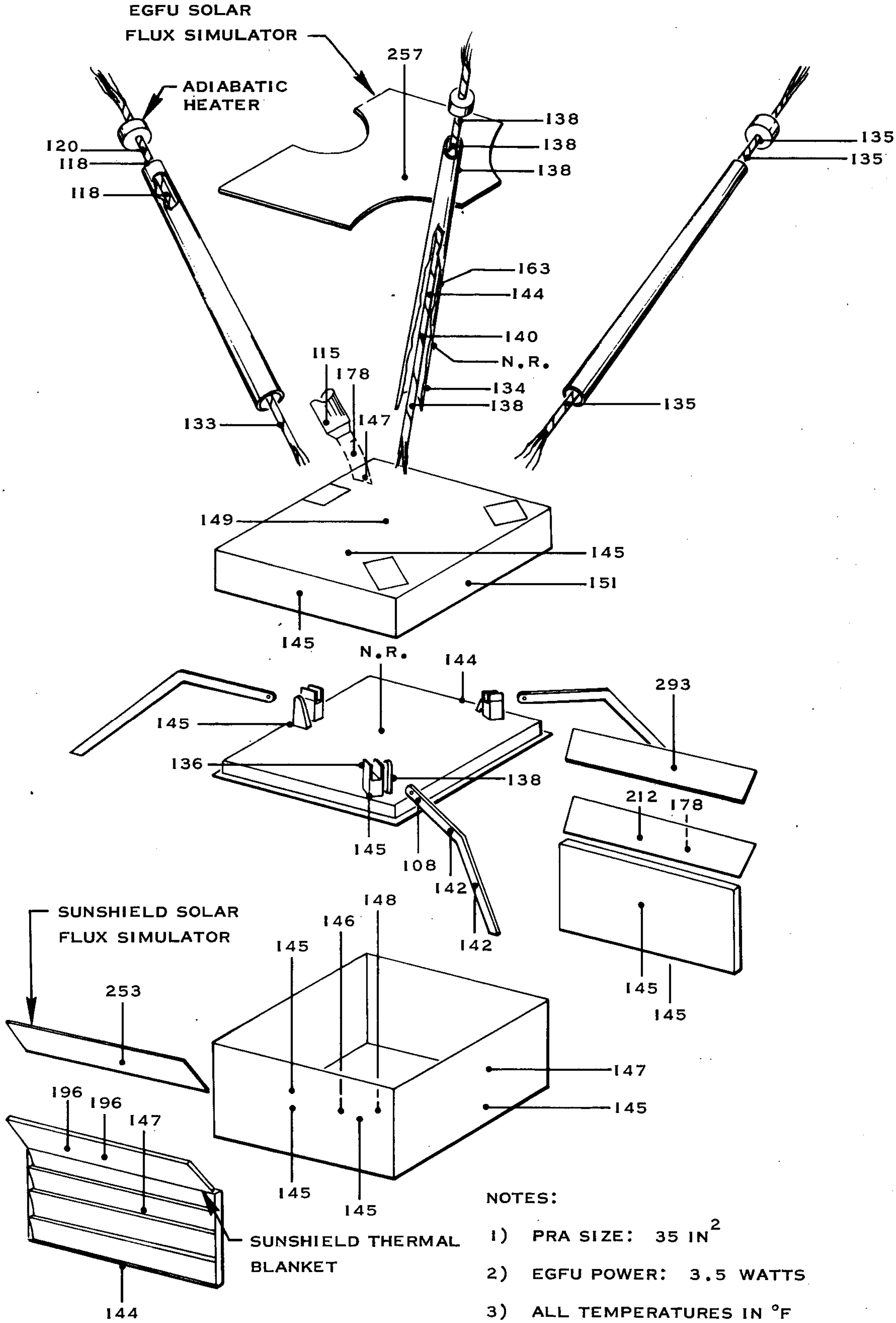


NOTES:

1) PRA SIZE: 35 IN^2 (TOTAL)

2) EGFU POWER: 3.5 NATTS

3) ALL TEMPERATURES IN °F

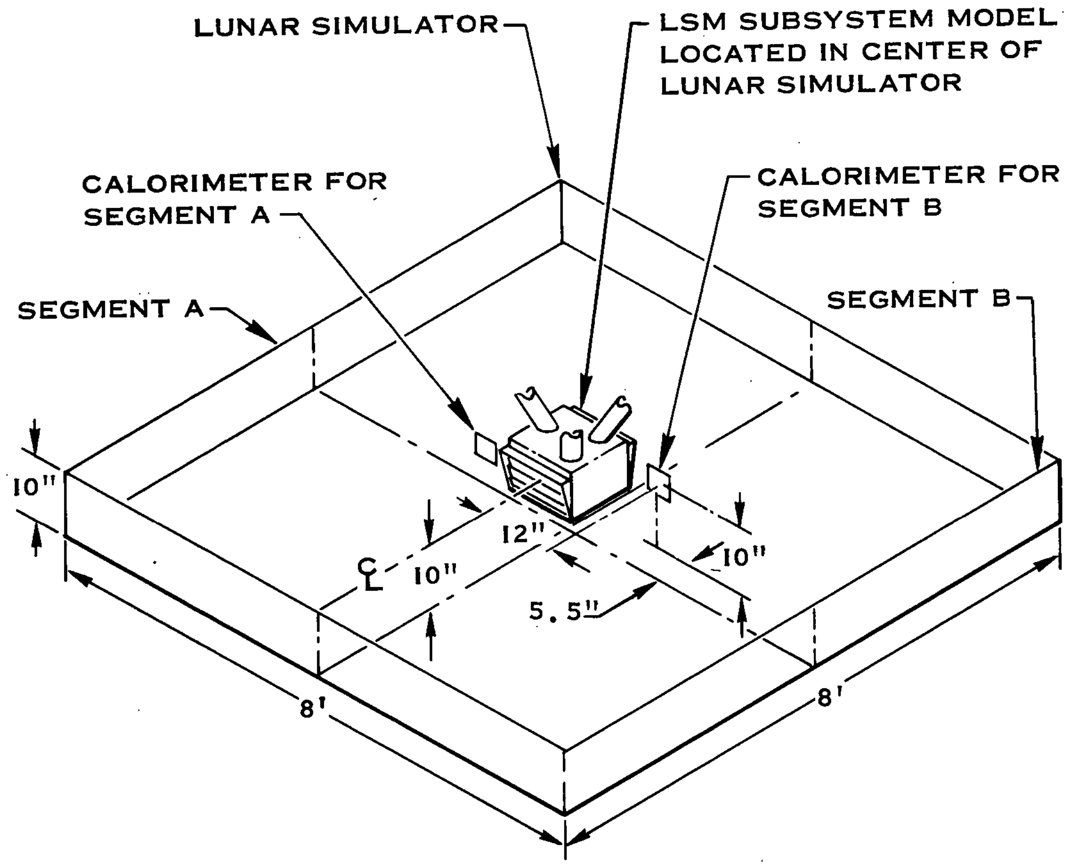


NOTES:

1) PRA SIZE: 35 IN^2

2) EGFU POWER: 3.5 WATTS

3) ALL TEMPERATURES IN °F



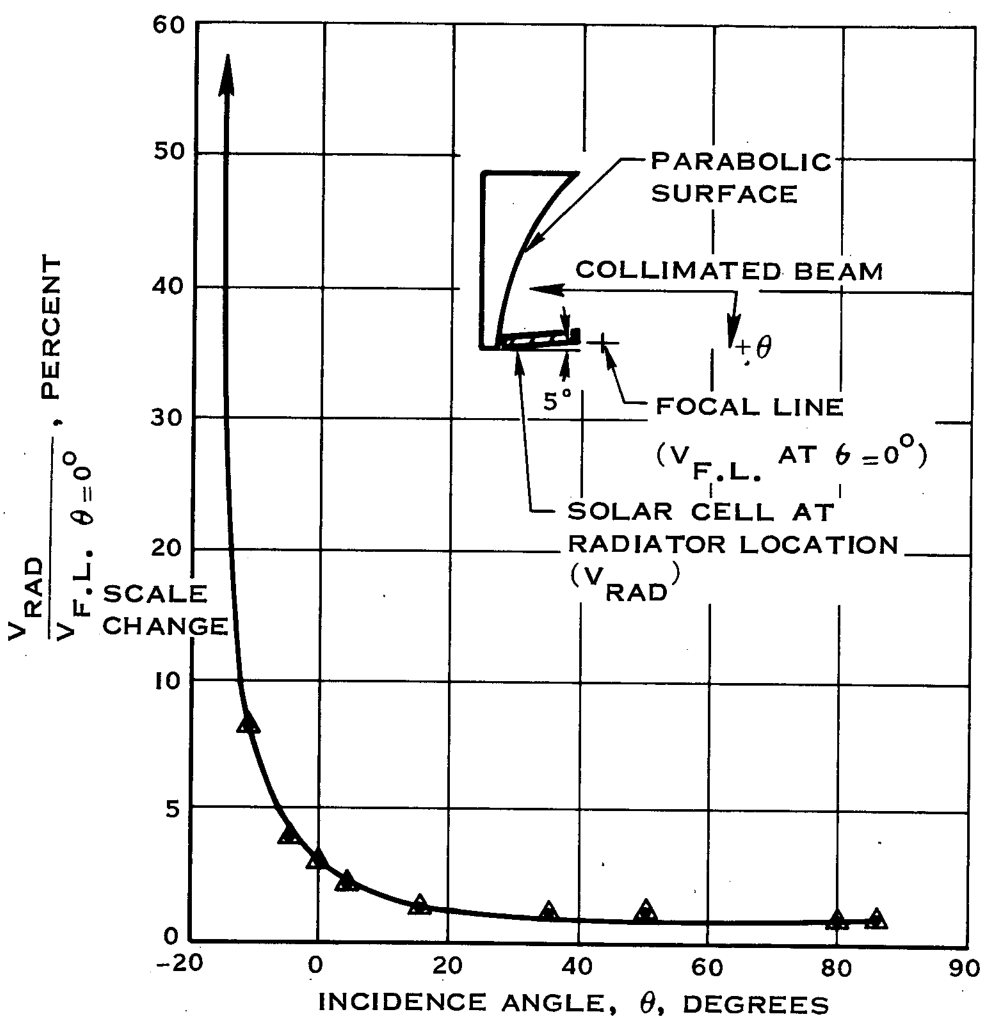
NOTES:

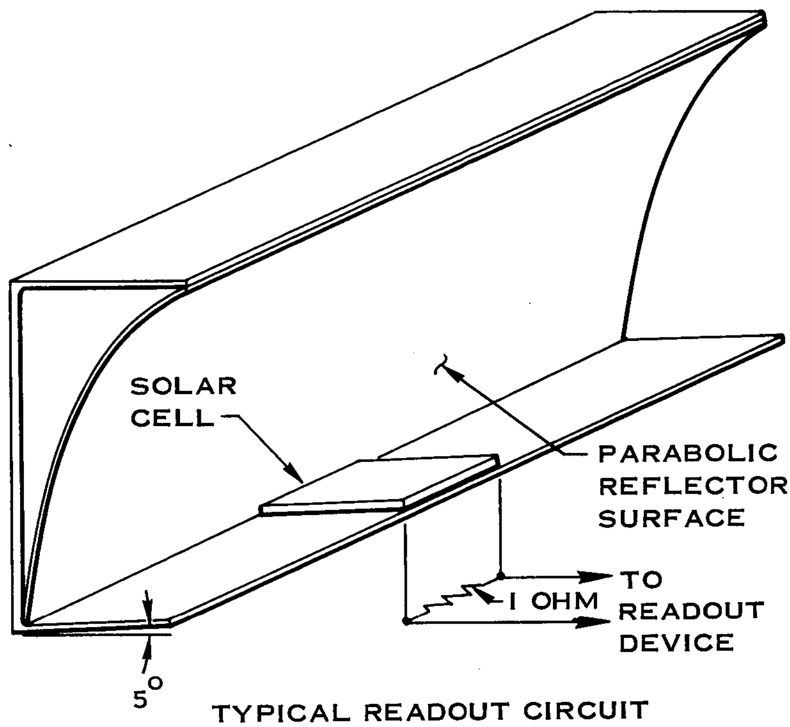
1) CALORIMETERS ARE LOCATED IN THE SAME VERTICAL PLANES AS THE PRA'S

2) CENTERS OF CALORIMETERS ARE ELEVATED 10" ABOVE LUNAR SIMULATOR

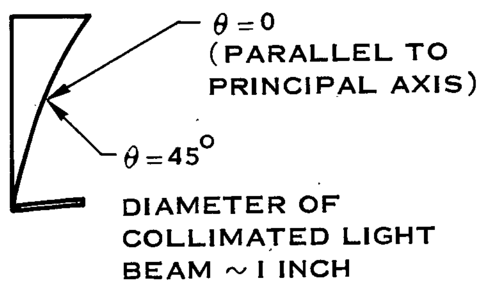
3) AVE. VIEW FACTOR OF MODEL VERTICAL SIDES TO LUNAR SIMULATOR ≈ 0.50

C. A. Zierman

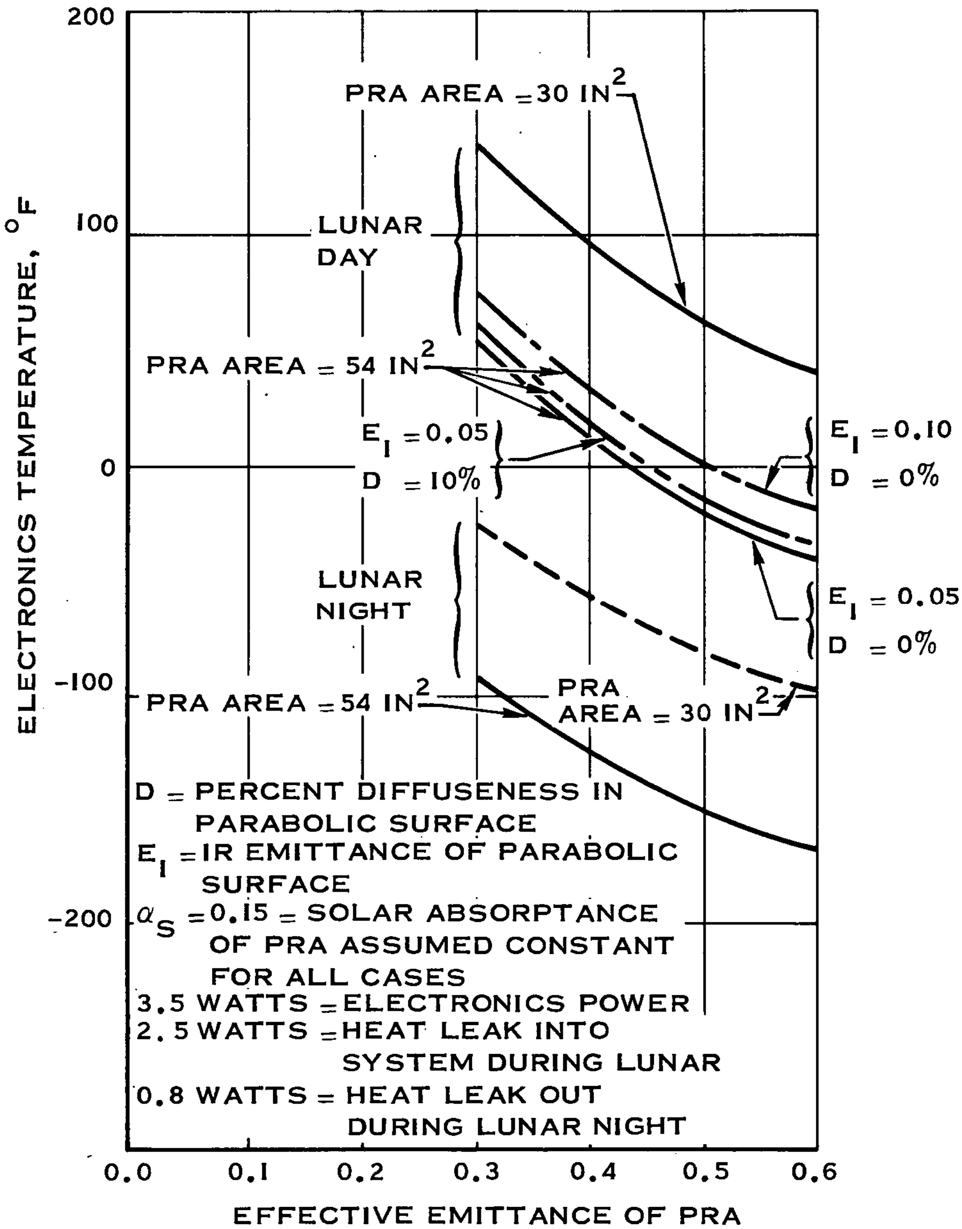

PARABOLIC SURFACE
COLLIMATED BEAM
+θ
5°
FOCAL LINE
(V F.L. AT θ = 0°)
SOLAR CELL AT RADIATOR LOCATION (V RAD)
SCALE CHANGE
V RAD / V F.L. θ=0°, PERCENT
INCIDENCE ANGLE, θ, DEGREES
60
50
40
30
20
10
5
0
-20
0
20
40
60
80
90



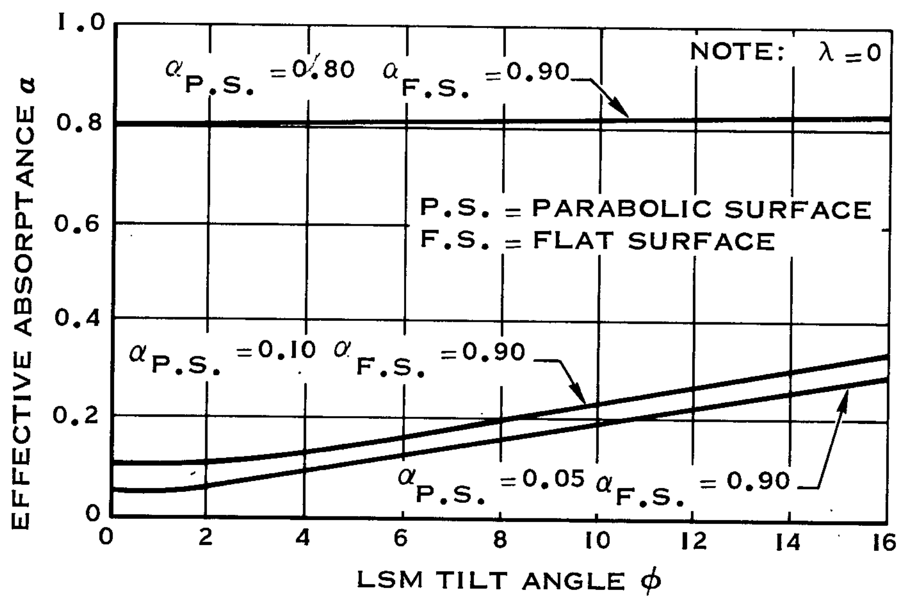
TYPICAL READOUT CIRCUIT
FOR SOLAR CELLS



NOTE: PLANE OF PRINCIPAL AXIS OFFSET 5^{o} FROM HORIZONTAL

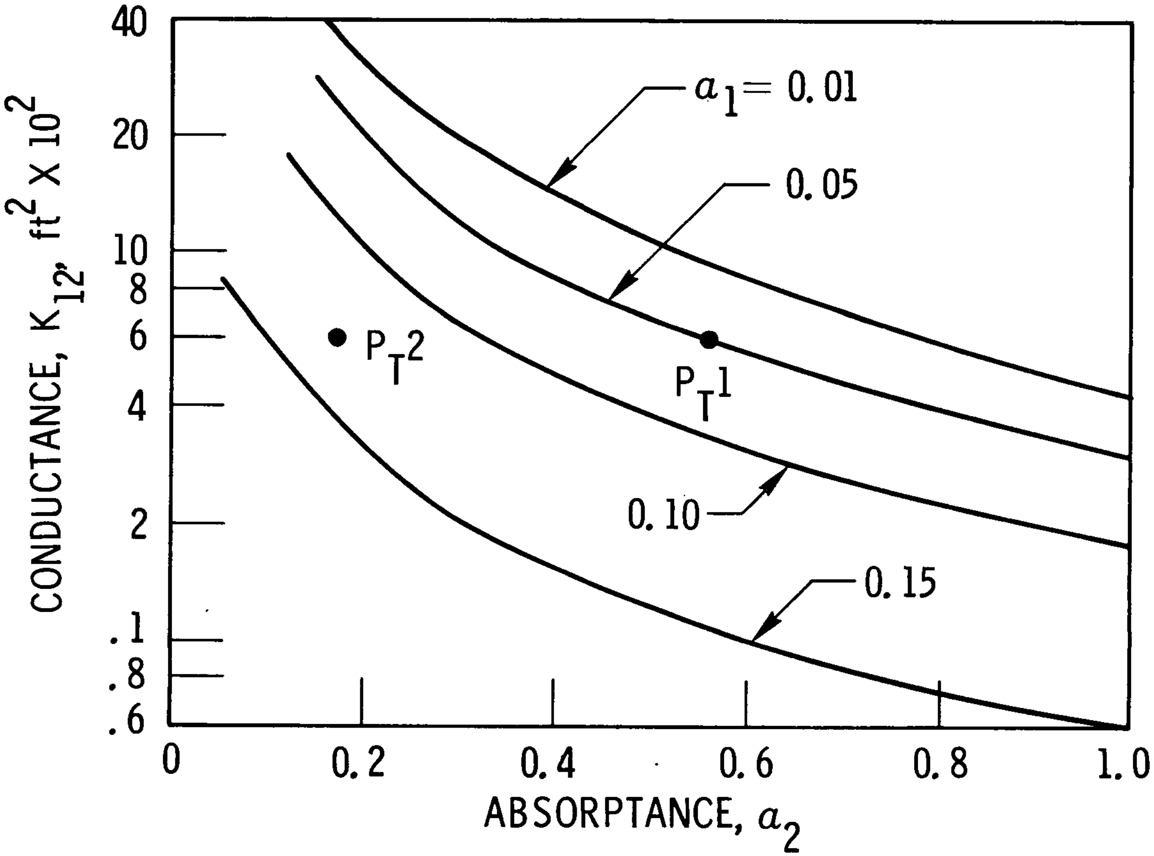


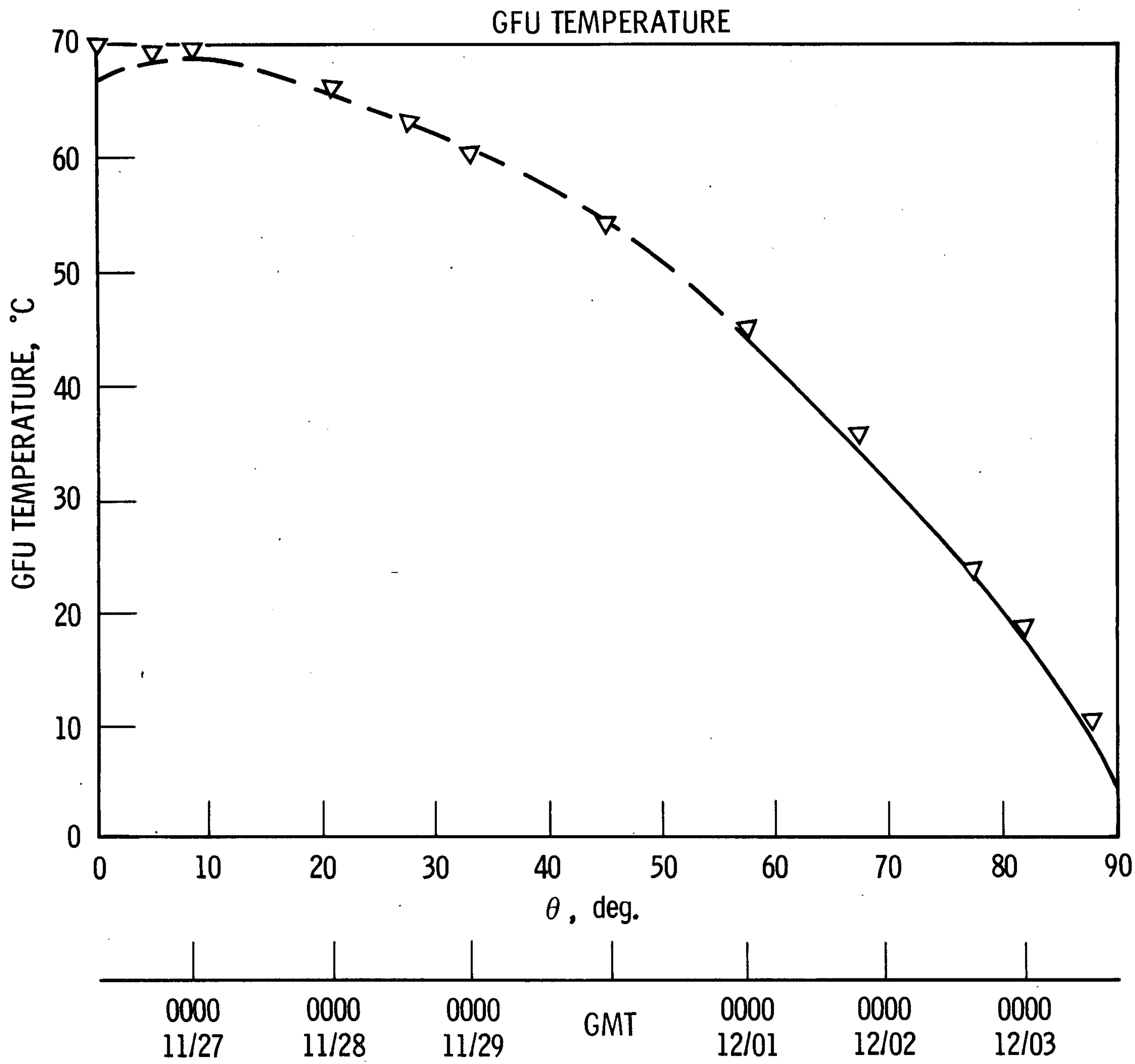
200
100
0
-100
-200
ELECTRONICS TEMPERATURE, °F
0.0
0.1
0.2
0.3
0.4
0.5
0.6
EFFECTIVE EMITTANCE OF PRA
PRA AREA = 30 IN²
LUNAR DAY
PRA AREA = 54 IN²
E_I = 0.05
D = 10%
E_I = 0.10
D = 0%
E_I = 0.05
D = 0%
LUNAR NIGHT
PRA AREA = 54 IN²
PRA AREA = 30 IN²
D = PERCENT DIFFUSENESS IN PARABOLIC SURFACE
E_I = IR EMITTANCE OF PARABOLIC SURFACE
α_S = 0.15 = SOLAR ABSORPTANCE OF PRA ASSUMED CONSTANT FOR ALL CASES
3.5 WATTS = ELECTRONICS POWER
2.5 WATTS = HEAT LEAK INTO SYSTEM DURING LUNAR
0.8 WATTS = HEAT LEAK OUT DURING LUNAR NIGHT



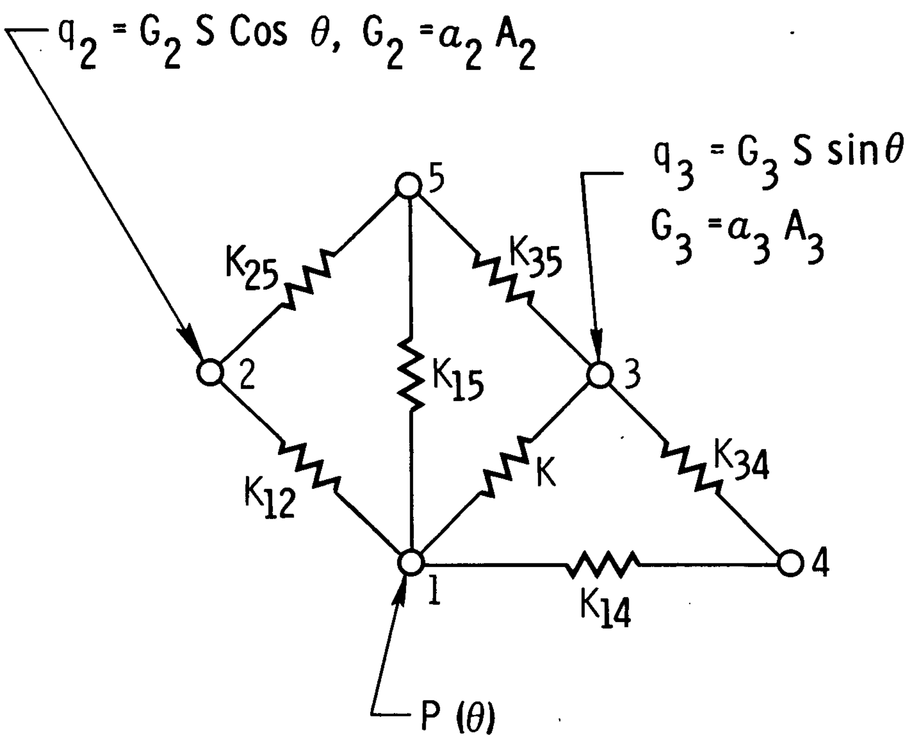
NOTE: $\lambda = 0$
$\alpha_{P.S.} = 0.80$ $\alpha_{F.S.} = 0.90$
P.S. = PARABOLIC SURFACE
F.S. = FLAT SURFACE
$\alpha_{P.S.} = 0.10$ $\alpha_{F.S.} = 0.90$
$\alpha_{P.S.} = 0.05$ $\alpha_{F.S.} = 0.90$
EFFECTIVE ABSORPTANCE α
LSM TILT ANGLE ϕ
0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
14
16

CONDUCTANCE K_{12} AS A FUNCTION OF ABSORPTANCES a_1 AND a_2




GFU TEMPERATURE
GFU TEMPERATURE, °C
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
θ, deg.
0000 11/27
0000 11/28
0000 11/29
GMT
0000 12/01
0000 12/02
0000 12/03

FIVE NODE LSM THERMAL RADIATION MODEL



LEGEND

A_n	AREA OF NODE n, ft^2
K	CONDUCTANCE, ft^2
P	POWER DISSIPATION, WATTS
S	SOLAR HEAT FLUX, WATTS / ft^2
α_n	ABSORPTANCE OF NODE n

NODE	DESCRIPTION
1	PRA FRONTAL AREA AND GFU
2	TOP INSULATION BLANKET
3	SIDE INSULATION BLANKET
4	LUNAR SURFACE
5	SPACE

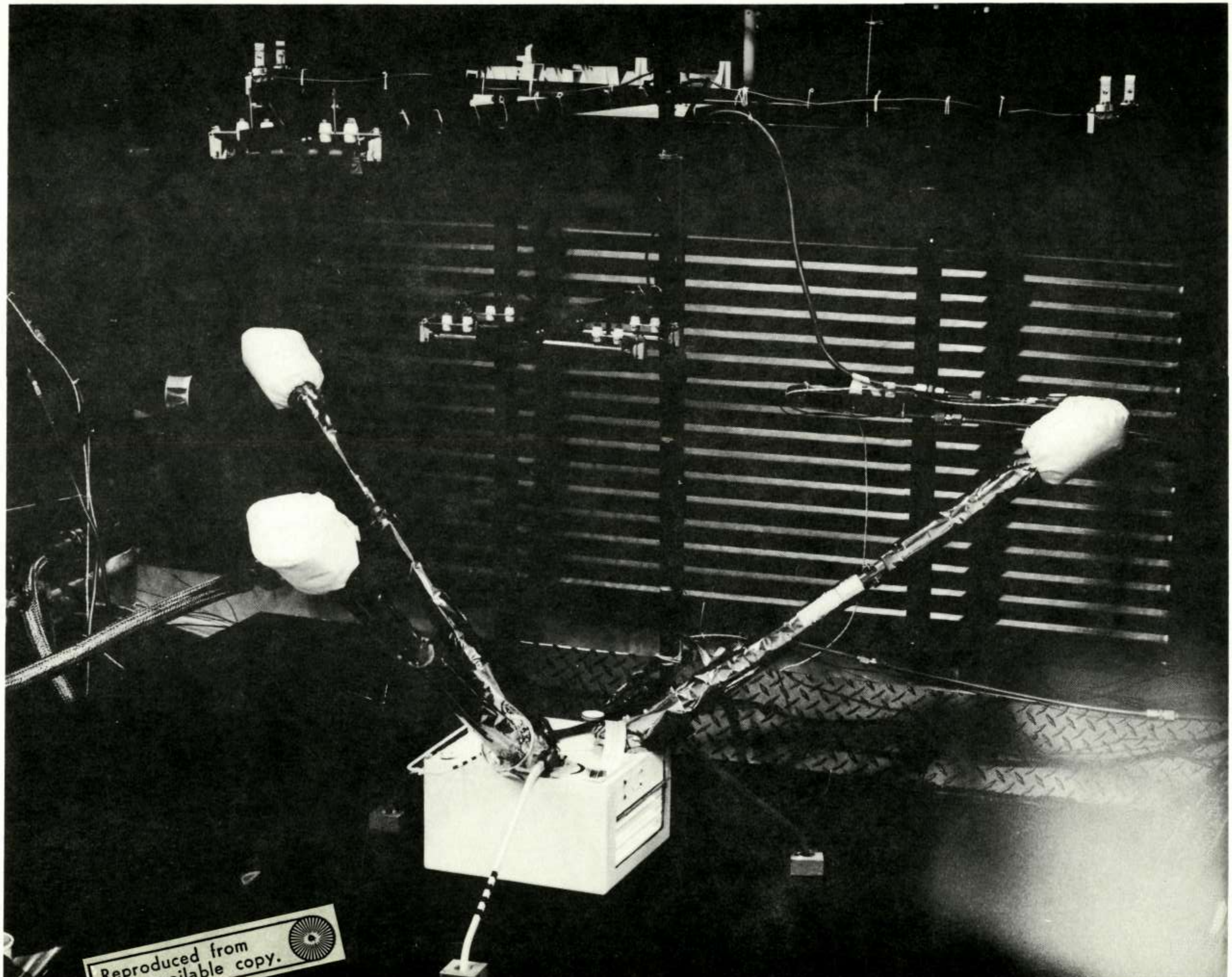
THERMAL DESIGN II

A) BENDIX THERMAL-VACUUM TESTS

B) LSM TEMPERATURES ON LUNAR SURFACE

C) ANALYSIS OF DISCREPANCIES

D) PRESENT CONFIGURATION



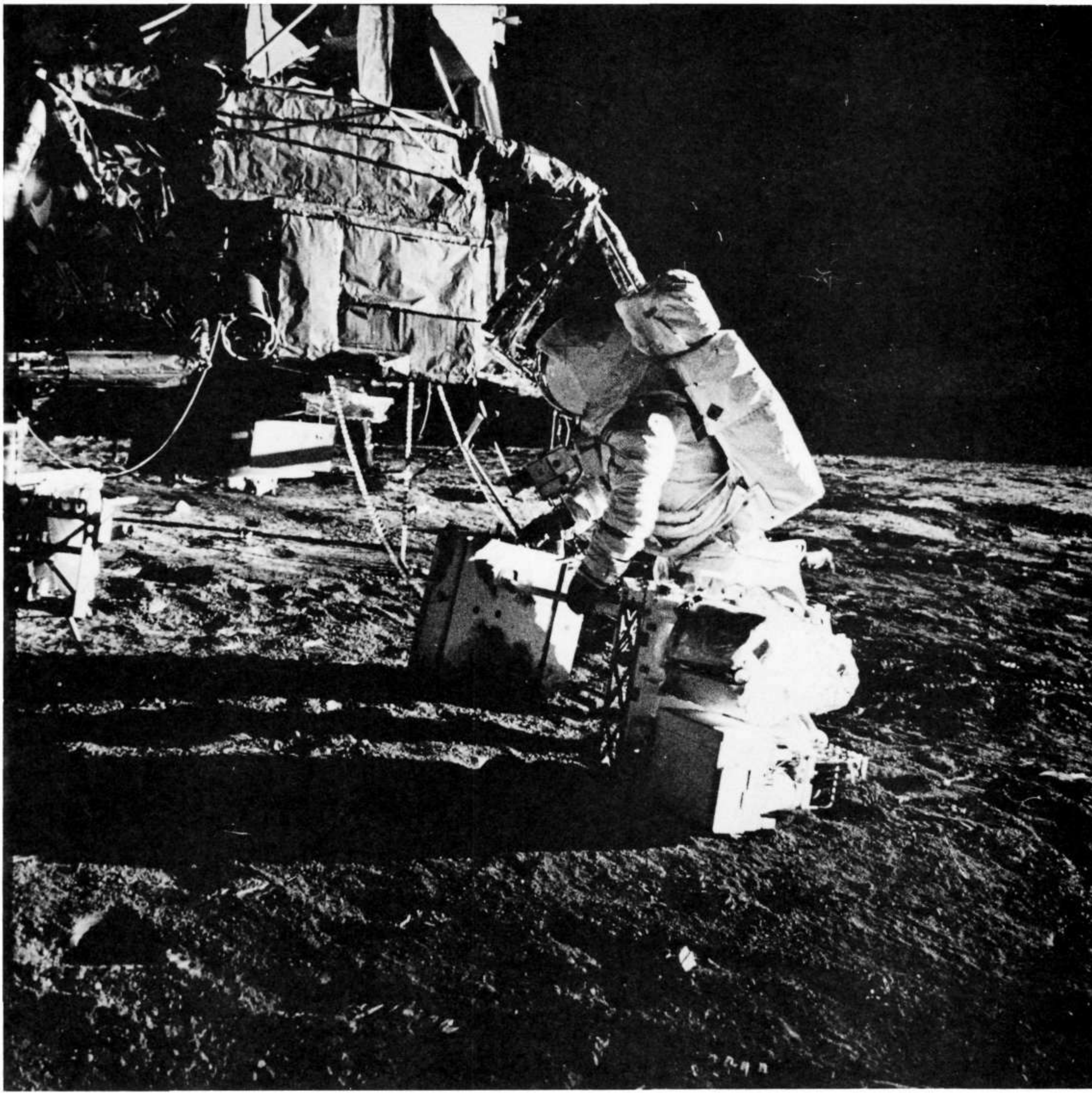
BENDIX THERMAL-VACUUM TEST RESULTS
QUAL/MISSION SIMULATION

COMPONENT	NOON °C	NIGHT °C
ELECTRONICS	52	-23
EGFU	47	-38
X SENSOR	40±5	40±5
Y SENSOR	40±5	40±5
Z SENSOR	40±5	40±5

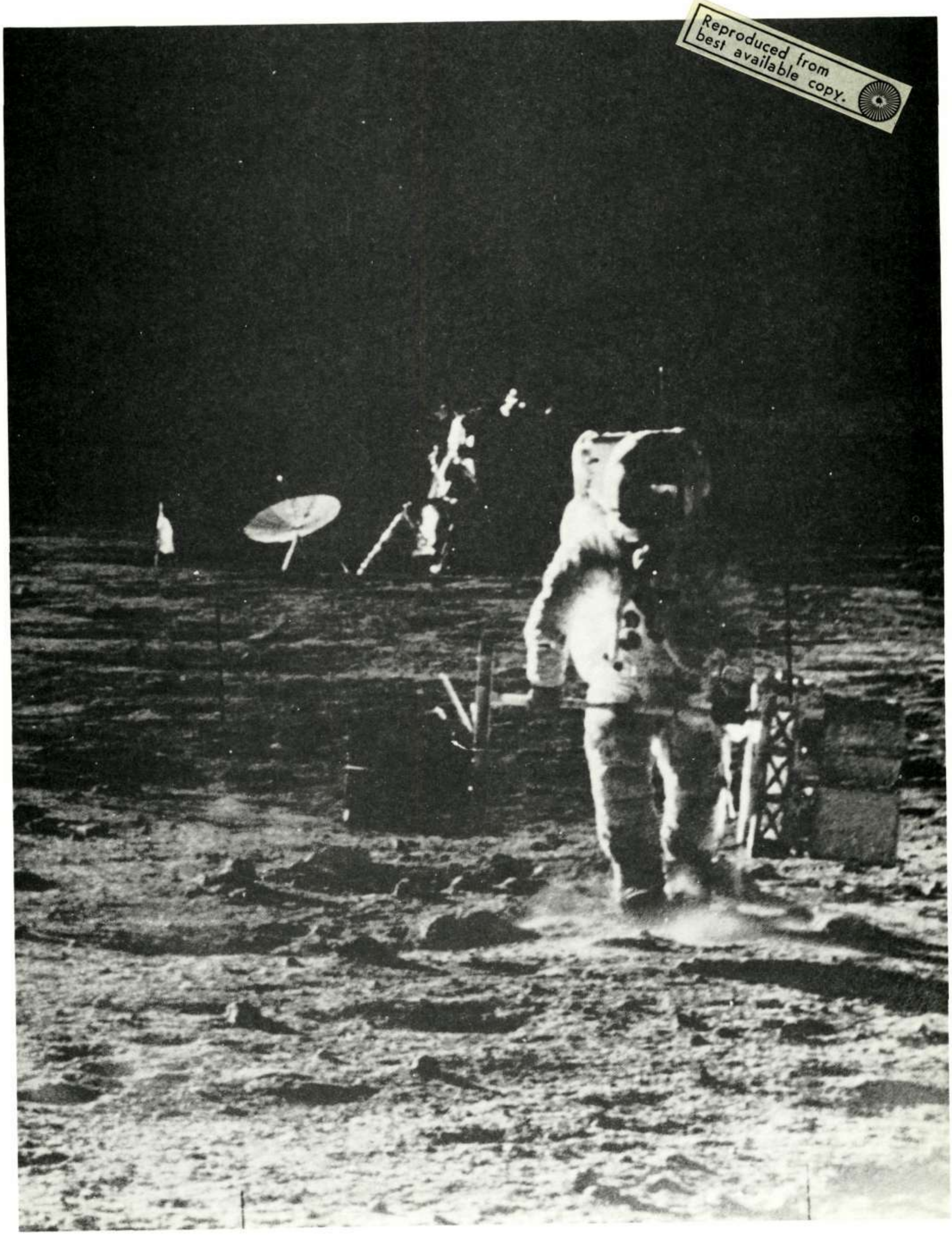
UPPER DESIGN TEMP: 65° C
LOWER DESIGN TEMP: -30° C

LUNAR SURFACE DEPLOYMENT

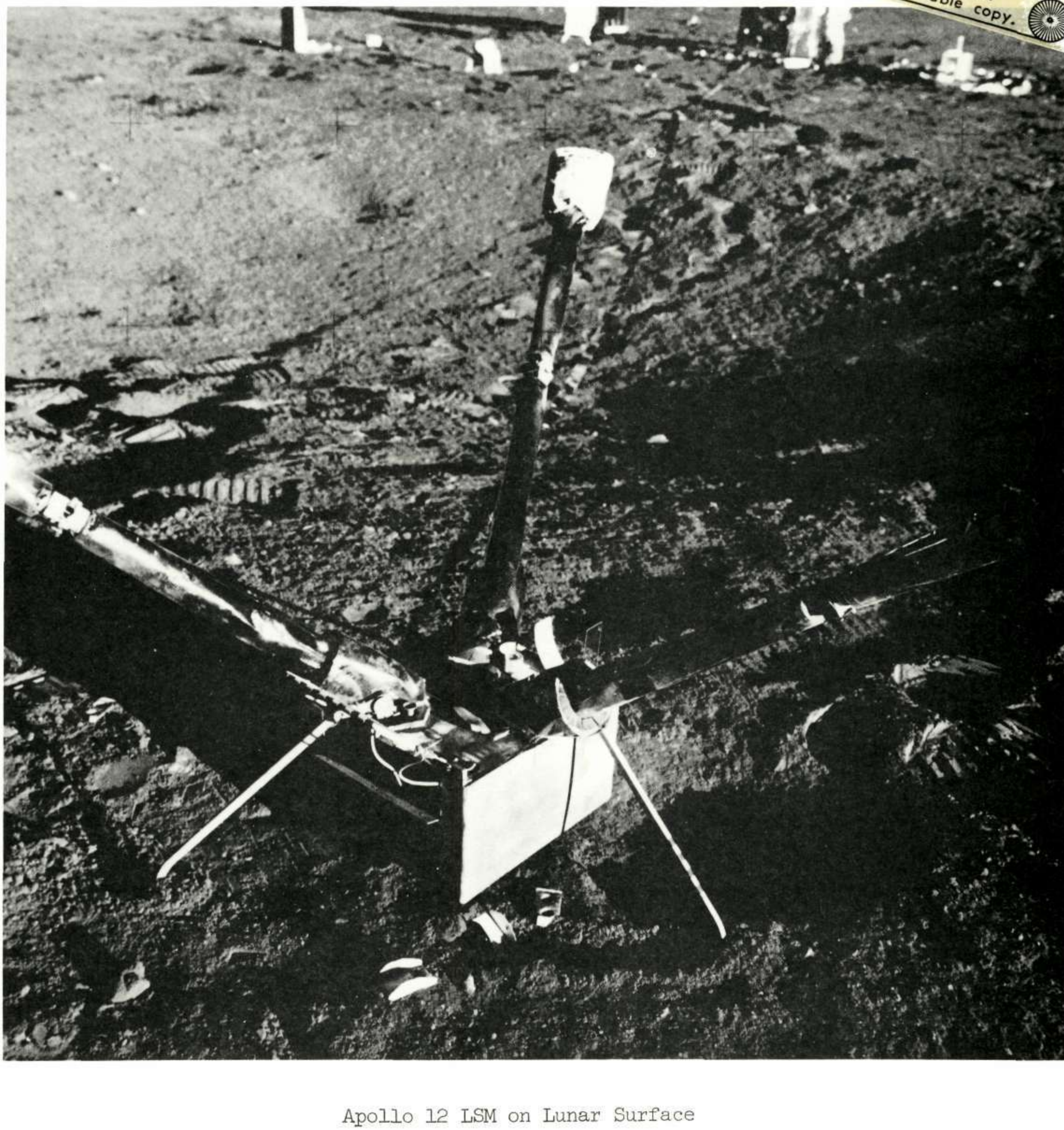
DUST



Apollo 12 ALSEP Lunar Operations - A

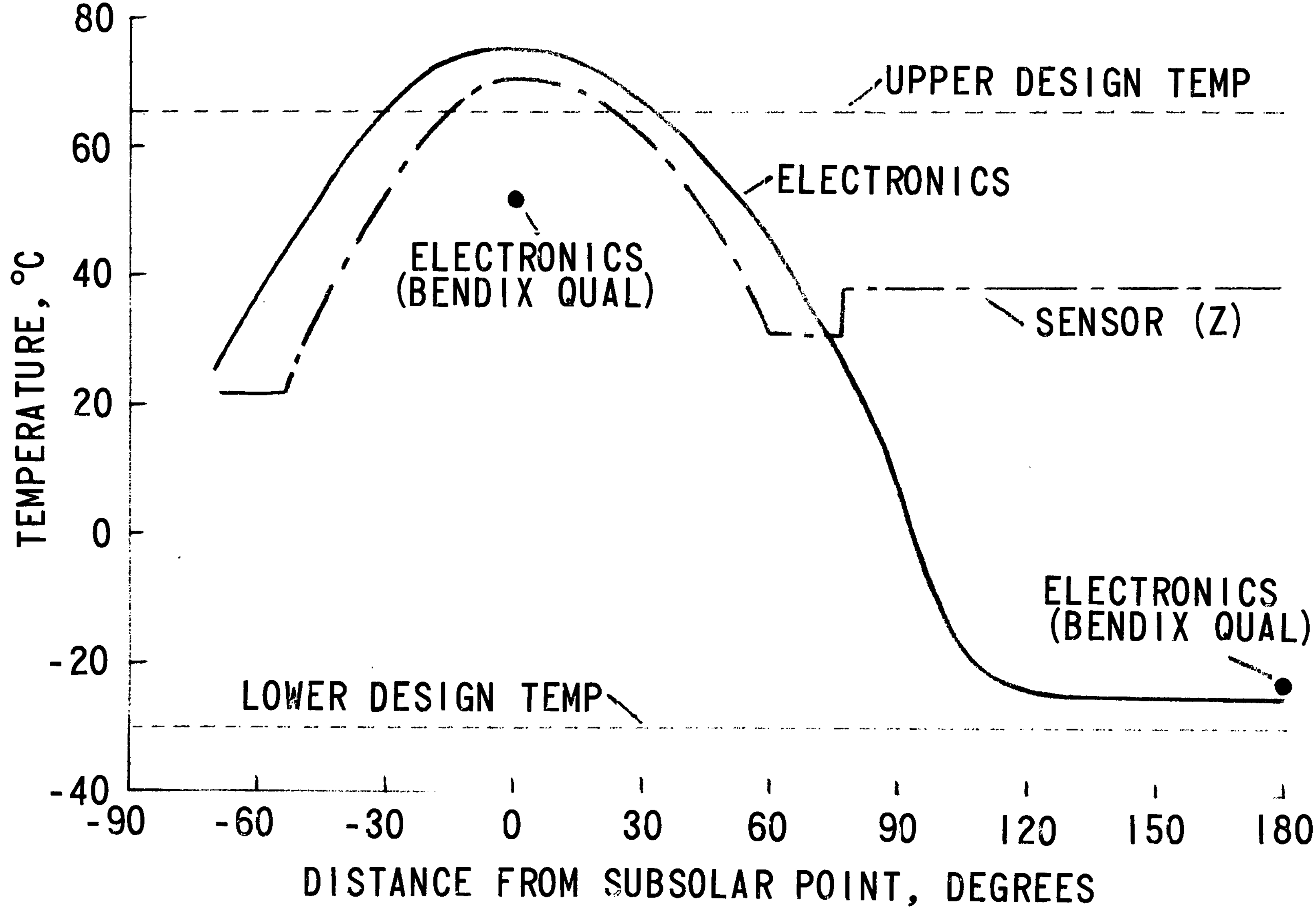


Apollo 12 ALSEP Lunar Operations - B



Apollo 12 LSM on Lunar Surface

LSM TEMPERATURES ON LUNAR SURFACE



PRESENT CONFIGURATION

A) SUN SHIELD

B) MASKING RADIATORS

EXPECTED PERFORMANCE

A) IF NO DUST:

COMPONENT	NOON °C	NIGHT °C
ELECTRONICS	45±10	-15±5
SENSORS	40±5	40±5

B) IF SAME AMOUNT OF DUST AS ENCOUNTERED ON APOLLO 12:

COMPONENT	NOON °C	NIGHT °C
ELECTRONICS	50±10	-15±5
SENSORS	70±5	40±5

QUALITY ASSURANCE

LUNAR SURFACE MAGNETOMETER R. AND Q. A. REQUIREMENTS

R. AND Q. A. REQUIREMENTS STATED IN NASA/ARC SPECIFICATION A11064 INCLUDE:

- QUALITY PLAN AND RELIABILITY PLAN FOR APPROVAL BY ARC
- RELIABILITY DESIGN SUPPORT
- PARTS AND MATERIALS PROGRAM FOR SELECTION, QUALIFICATION SCREENING AND CONTROL
- SUBCONTRACTOR AND SUPPLIER CONTROL
- TRAINING PROGRAMS
- DRAWING AND SPECIFICATION REVIEW AND APPROVAL
- QUALITY ENGINEERING, REVIEW AND APPROVAL OF FABRICATION DOCUMENTS AND PROCEDURES
- MATERIAL REVIEW BOARD WITH CUSTOMER REPRESENTATION
- QUALITY CONTROL BY INSPECTION AND TEST WITNESSING
- FAILURE ANALYSIS, REPORTING AND CORRECTIVE ACTION
- MONTHLY AUDITS AND REPORTS

LUNAR SURFACE MAGNETOMETER
ORGANIZATION AND PLANNING

- PHILCO-FORD PRODUCT ASSURANCE
- PHILCO-FORD LSM PROGRAM OFFICE
- PHILCO-FORD LSM DESIGN ASSURANCE
- AMES R & QA REPRESENTATIVE
- DCASO AT PHILCO-FORD
- MONTHLY R & QA REVIEW AND AUDIT MEETINGS
- MONTHLY R & QA STATUS REPORTS
- PLANNING DOCUMENTS
- RELIABILITY REPORTS
- DESIGN REVIEWS

LUNAR SURFACE MAGNETOMETER
PARTS SELECTION AND QUALIFICATION

- PARTS SELECTED FROM PIONEER APPROVED PARTS LIST WHERE POSSIBLE
- PARTS SELECTED FROM PHILCO-FORD PREFERRED PARTS LIST, AND SUPPORTING DOCUMENTATION SUPPLIED TO ARC FOR APPROVAL
- RELIABILITY DESIGN SUPPORT AND PARTS SPECIALISTS
- INTEGRATED CIRCUITS – QUALIFICATION TEST RUN FOR 1000 HOURS ON 200 DUAL-CHIP UNITS
- PARTS SPECIFICATIONS PREPARED FOR ALL PARTS AND PART NUMBERS ASSIGNED
- NON-MAGNETIC LEAD MATERIALS AND CONSTRUCTION REQUIRED

C.3

LUNAR SURFACE MAGNETOMETER
PARTS SELECTION AND QUALIFICATION (CONTINUED)

PARTS SCREENING AND CONTROL

- SCREENING REQUIREMENTS ESTABLISHED AND PROCEDURES WRITTEN
- SPECIAL SCREENING PROGRAM FOUND NECESSARY FOR IC'S. INCLUDED 168-HOUR OPERATING BURN-IN AT 125 DEGREES CENTIGRADE AND PARAMETER DRIFT ANALYSIS
- ALL PARTS AND MATERIALS USED WERE MAGNETICALLY SCREENED
- POSITIVE CONTROL OF SCREENED PARTS AND MATERIALS THROUGH COLOR CODES, ETC.
- BONDED STORES OPERATION
- FAILURE ANALYSIS AND CORRECTIVE ACTION

LUNAR SURFACE MAGNETOMETER
CONTROL OF FABRICATION & ASSEMBLY OPERATIONS

- FABRICATION AND INSPECTION PLAN
- DRAWING REVIEW, RELEASE, AND CONTROL
- CHANGE CONTROL BOARD AND SPECIFICATION REVIEW BOARD
- MANUFACTURING STANDARDS AND PROCESS CONTROLS
- CERTIFICATION OF OPERATORS AND EQUIPMENT
- FLOW GUIDES AND SHOP ORDERS
- PRODUCTION PROCEDURE-INSPECTION GUIDES
- CONFIGURATION CONTROL: PART NUMBER, SERIAL NUMBER, AND REVISION LETTER
- QUALITY CONTROL INSTRUCTIONS
- MATERIAL REVIEW BOARD AND CORRECTIVE ACTION

LSM FABRICATION/INSPECTION PLAN

A.0	ELECTRONICS/MECHANICAL PARTS
A.1	Receiving Inspection
A.2	Electrical/Magnetic Screen - Code - QC Inspect.
A.3	Bonded Stores - Kit - To steps 3.0,5.0

1.0	VOLTAGE GROUND PLANE
1.1	Fab printed circuit per print
1.2	QC Inspect
1.3	Punch tool holes, drill and trim
1.4	Pierce window holes
1.5	QC Inspect
1.6	Bonded Stores to step 3.3

2.0	PRINTED WIRING BOARD
2.1	Fab printed circuit per print
2.2	QC Inspect
2.3	Punch, trim and hot form
2.4	QC Inspect
2.5	Bonded stores to step 3.1

3.0	PRINTED WIRING BOARD ASSEMBLY
3.1	Weld jumpers and feed throughs
3.2	QC Inspect
3.3	Install Power and Ground Plane
3.4	QC Inspect
3.5	Weld leads and integrated circuits
3.6	QC Inspect
3.7	Electrical test
3.8	QC Inspect - GSI
3.9	Bonded stores to step 4.1 or 6.1

4.0	INTEGRATED CIRCUIT MODULE ASSEMBLY
4.1	Install IC cards in assembly fixture
4.2	QC Inspect
4.3	Weld interconnections and identify
4.4	QC Inspect
4.5	Pre-pot electrical test
4.6	QC Inspect - GSI
4.7	Bond Leads to header
4.8	QC Inspect
4.9	Bonded stores to step 6.1 or 10.1

5.0	CORDWOOD MODULE ASSEMBLY
5.1	Fab module mylar substrates per print
5.2	QC Inspect
5.3	Punch and trim
5.4	Load components
5.5	QC Inspect
5.6	Weld and tag with P/N and S/N
5.7	QC Inspect
5.8	Electrical test
5.9	QC Inspect - GSI
5.10	Encapsulation or step 6.1
5.11	QC Inspect
5.12	Post-pot electrical test
5.13	QC Inspect - (Verify test data)
5.14	Bonded stores to step 6.1 or 10.1

6.0	IC/CW MODULE ASSEMBLY
6.1	Mount mods on header per print
6.2	Electrical test - Install S-A-T parts per print
6.3	QC Inspect GSI
6.4	Encapsulate
6.5	Electrical test and identify
6.6	QC Inspect (Verify Test Data)
6.7	Bonded Stores to Step 10.1

7.0	INTERCONNECT BOARD ASSEMBLIES
7.1	Fab identification mylar per print
7.2	QC Inspect
7.3	Fab interconnect PWB's per print
7.4	QC Inspect
7.5	Weld, laminate and identify
7.6	Pre-pot electrical test
7.7	QC Inspect
7.8	This step intentionally deleted.
7.9	Electrical test
7.10	QC Inspect GSI
7.11	Bonded Stores to step 10.1

8.0	CONNECTOR ASSEMBLIES
8.1	Fab per print
8.2	QC Inspect GSI (Solder)
8.3	Encapsulate
8.4	Electrical test, QC Inspect
8.5	Bonded Stores to step 10.2

LSM FABRICATION/INSPECTION PLAN

9.0	FAB CHASSIS/COVER/MISC HARDWARE
9.1	Machine and finish per print
9.2	Identify
9.3	QC Inspect
9.4	Bonded Stores to step 10.1

10.0	PROCESSOR ELECTRONICS ASSEMBLY
10.1	Install modules on mother boards (temporary)
10.2	Mount temporary connector and mother board assemblies on chassis and torque
10.3	Pretest Processor Electronics QC Surveillance - Mate with sensors and GFU as required
10.4	Final assembly. Install "Select At Test" parts
10.5	Complete welding operations
10.6	QC Inspect GSI
10.7	Conformal coat and encapsulate
10.8	QC Inspect
10.9	Mount connector and mother boards on chassis and torque
10.10	QC Inspect
10.11	Install covers
10.12	Test per SB173495, QC Witness. (Review test data)
10.13	Bonded Stores to step 12.1

11.0	ELECTROMECHANICAL SUBSYSTEM ASSEMBLY
11.1	Fab parts per print - QC Inspect
11.2	Assemble GFU per print and Operator Guide QC Inspect. Electrical test.
11.3	Assemble Sensor Arm Assemblies per print and Operator Guide. QC Inspect. Electrical test.
11.4	Assemble Legs, Sun Indicator etc. per print and Operator Guide. QC Inspect.
11.5	Integrate Electro-mechan. subsystem less covers, Thermal Control System etc.
11.6	QC Inspect - GSI
11.7	Test per SB 175820, QC Witness,
11.8	Bonded stores to step 12.1

12.0	LSM INTEGRATION
12.1	Integrate Processor Electronics and Electro-mechanical Subsystem - QC Witness - GSI
12.2	Pre-acceptance tests, final adjustments - QC Monitor
12.3	Install S-A-T parts & solder, QC Inspect GSI
12.4	Conformal coat - QC Inspect
12.5	Install Covers etc. QC Inspect GSI
12.6	Install P.R.A., etc. per Shop Orders
12.7	QC Inspect - GSI
*12.8	Perform Acceptance test per SB173080-QC and DCAS Witness - GSI
12.9	Prepare for shipping, QC Inspect
12.10	Prepare Data Package, Review Documentation (QC)

* For Qual Model - Qual. Test per SR173080

LUNAR SURFACE MAGNETOMETER
TEST PLANNING AND SURVEILLANCE

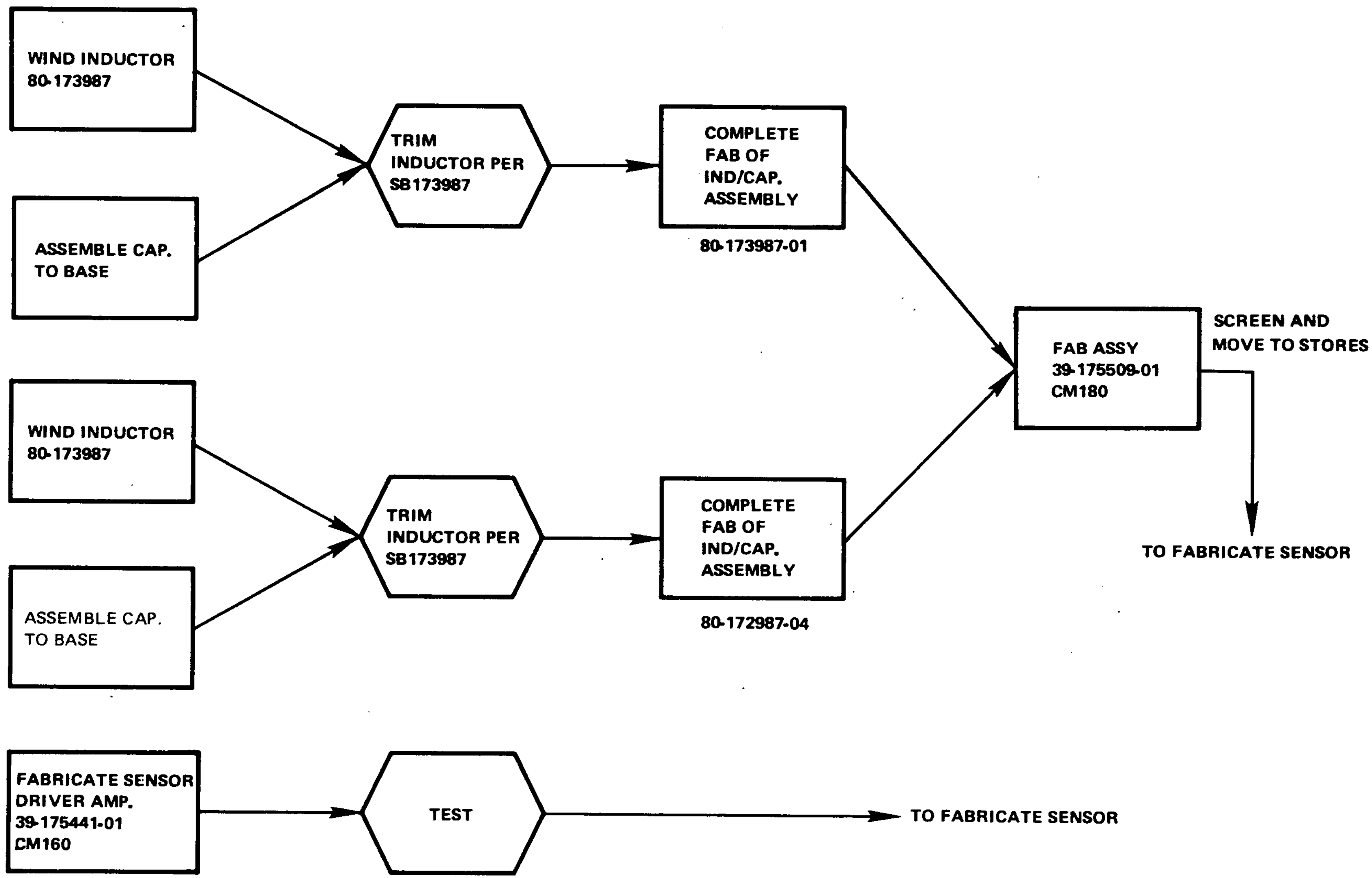
- TEST SPECIFICATION REVIEW AND RELEASE
- TEST PROCEDURE REVIEW AND RELEASE
- SURVEILLANCE OF IN-PROCESS TESTS
- WITNESSING OF QUALIFICATION AND ACCEPTANCE TESTS
- CONTROL AND CALIBRATION OF TEST EQUIPMENT

PACKAGING AND SHIPPING INSPECTION

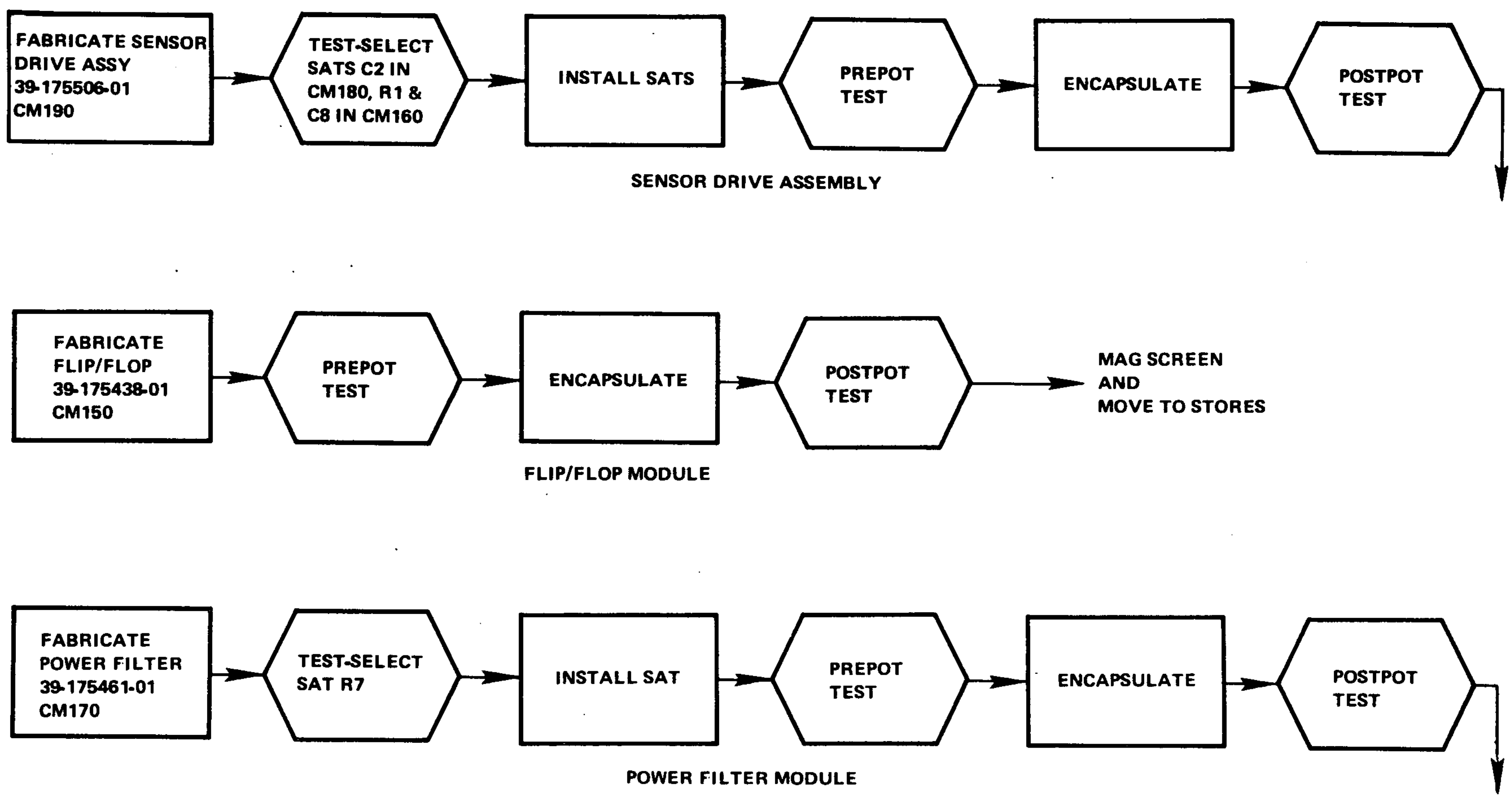
- PACKAGING PROCEDURE AND CHECKLIST
- DATA PACKAGE
- DD250

TESTING

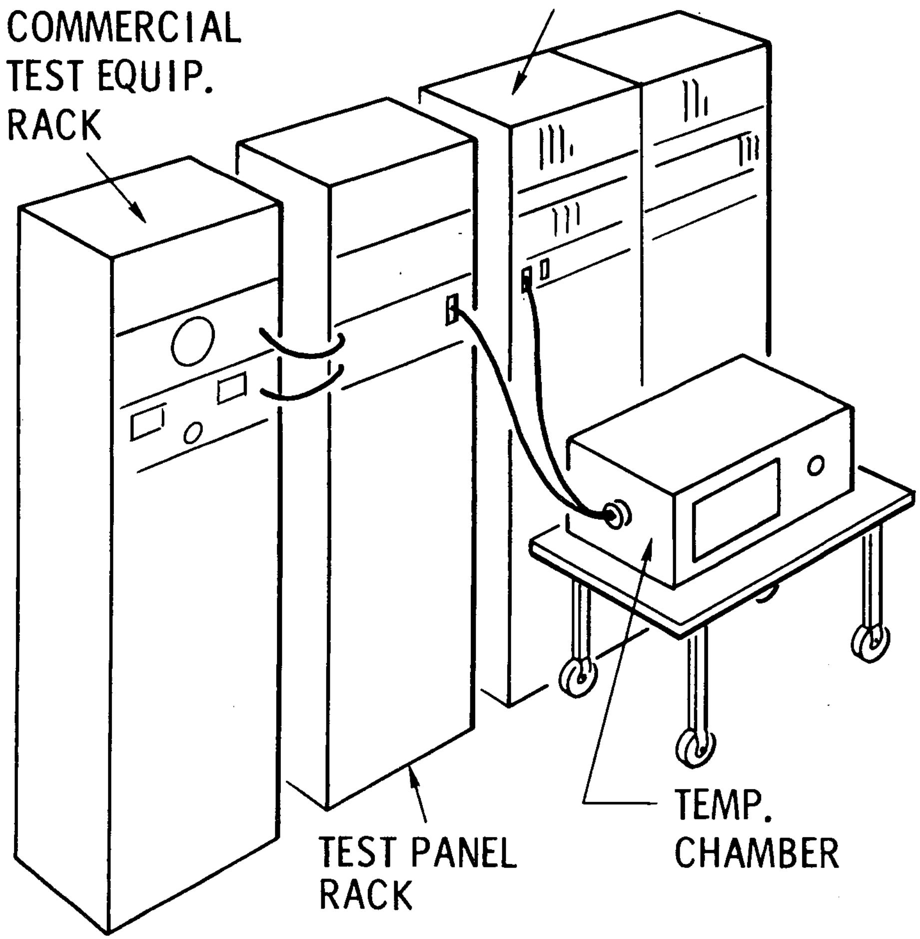
LSM IN-PROCESS TEST FLOW (EXAMPLE)



LSM IN-PROCESS TEST FLOW(CONT.)
(EXAMPLE)



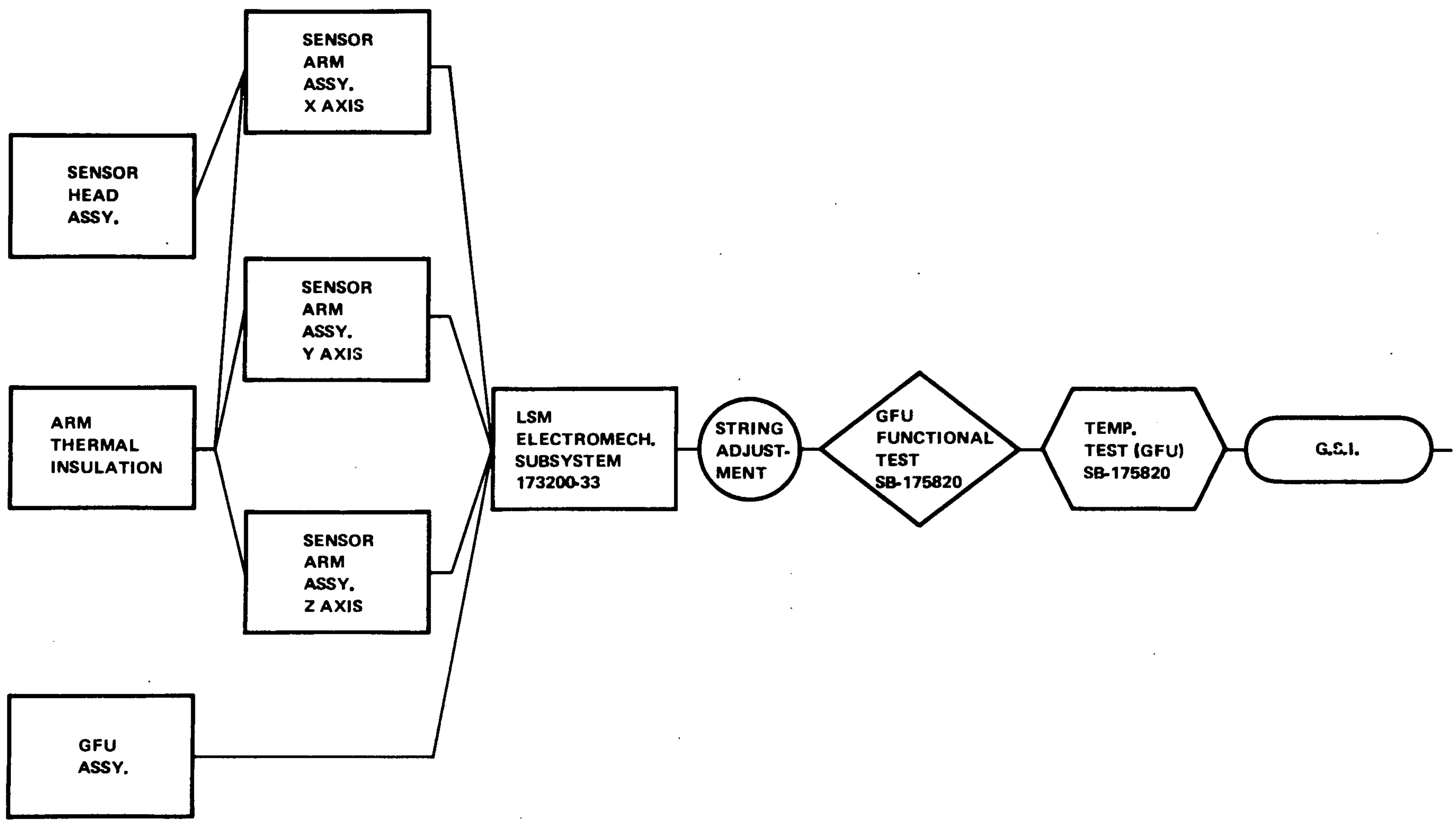
TYPICAL LSM IN-PROCESS SUBSYSTEM TEST
(SHOWING TEMP. TEST IN PROGRESS)



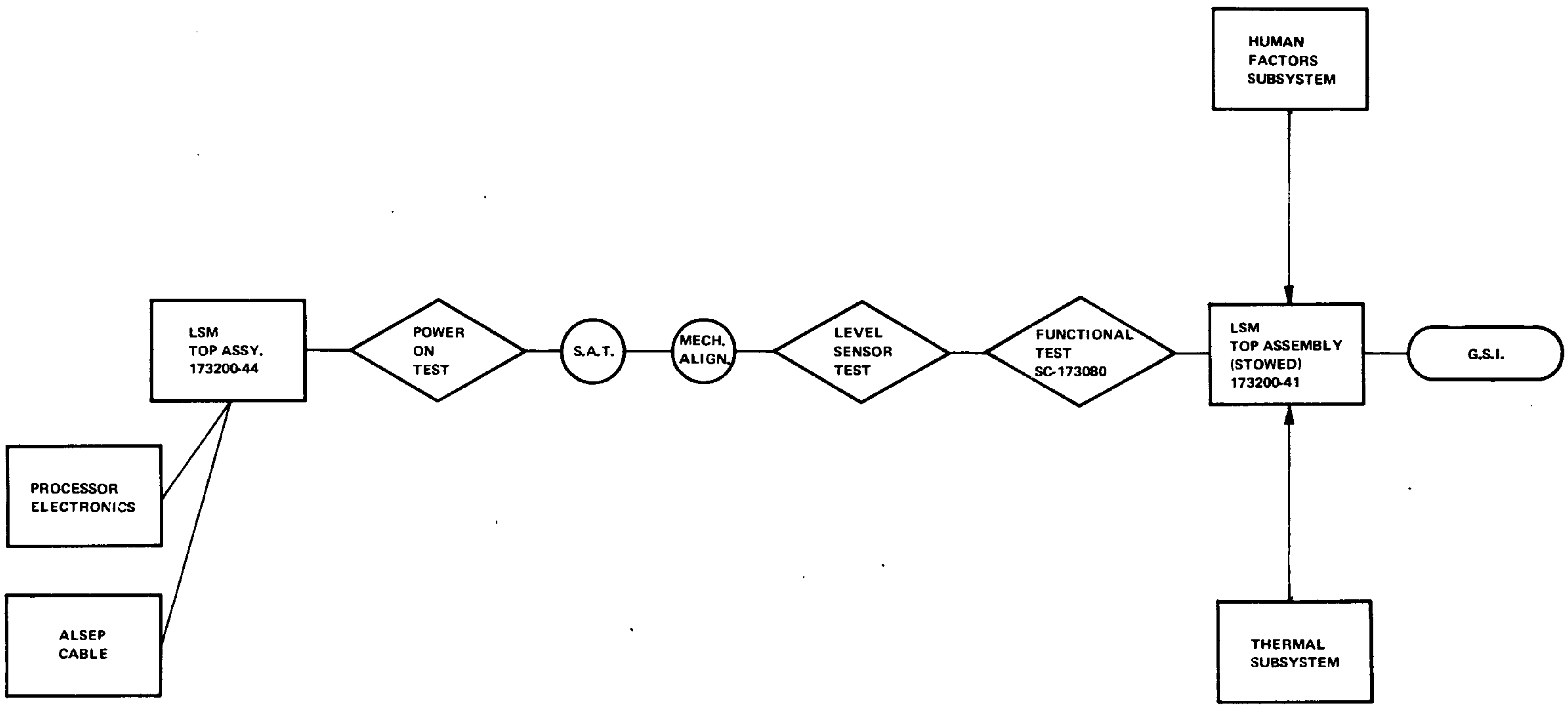
TEST SEQUENCE

1. SUBSYSTEM IS FABRICATED FROM PREVIOUSLY TESTED SUBSTRATES.
2. SUBSYSTEM IS RECEIVED INTO TEST AREA FROM FABRICATION MOUNTED ON A SUITABLE TEST FIXTURE.
3. CONNECTION BETWEEN THE S/S AND THE BREADBOARD AND TEST PANELS IS MADE BY MEANS OF SPECIAL ADAPTER CABLES.
4. THE SUBSYSTEM IS THEN TESTED IN ACCORDANCE WITH AN APPROVED PROCEDURE.
5. THE S/S IS ROUTED TO BONDED STORES FOR FURTHER ASSEMBLY.

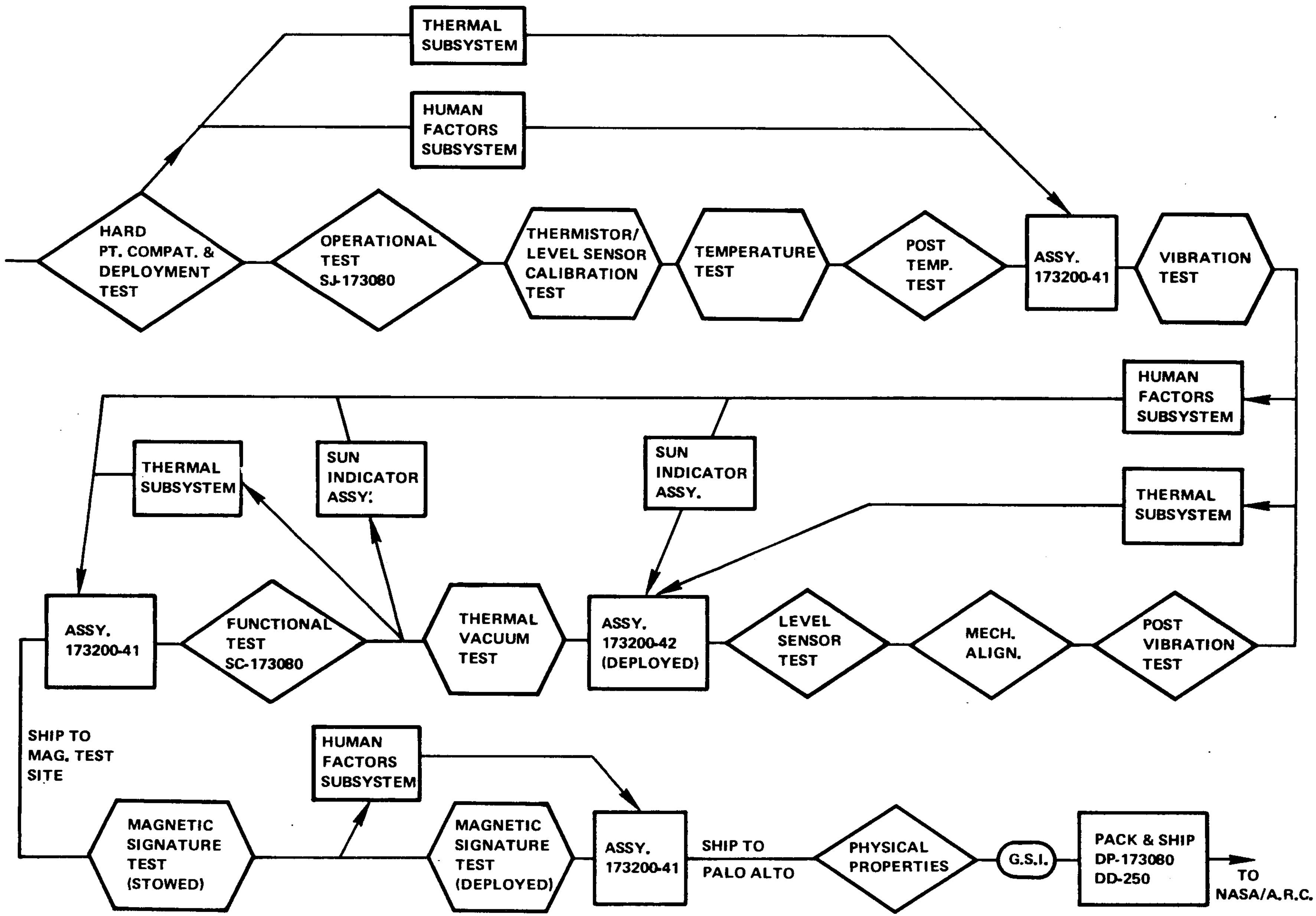
GFU ASSEMBLY AND TEST



SYSTEM ASSEMBLY PRE-ACCEPTANCE TEST



SYSTEM ACCEPTANCE TEST



DEVELOPMENT TESTING

BREADBOARD

LSM ENGINEERING MODEL NO. 1

LSM ENGINEERING MODEL NO. 2

PROTOTYPE LSM NO. 1

QUAL. MODEL LSM NO. 2 (SYSTEM QUAL.)

ANOMALIES REVIEW